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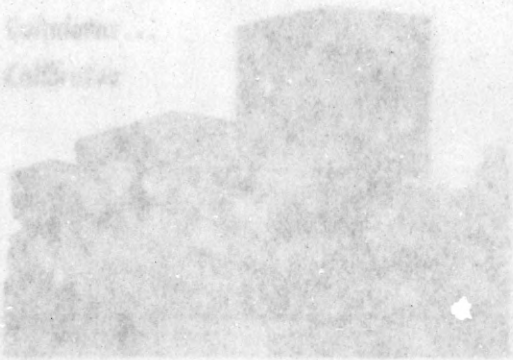

Journal
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Devoted to Science and the Mechanic Arts

Vol. 238 JULY, 1944 No. 1

SEASONAL VARIATIONS OF ULTRAVIOLET ENERGY IN DAYLIGHT.

BY

MATTHEW LUCKIESH, A. H. TAYLOR AND G. P. KERR.

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It has been conclusively proved that the short-wave ultraviolet energy in sunlight and skylight effectively prevents and cures rickets if the exposure is adequate. The particularly effective ultraviolet energy is that close to the short-wave end of the solar spectrum—shorter than λ 3200 (Angstroms). The intensity of solar energy in this spectral region is greatly influenced by the thickness of the atmosphere traversed by the solar radiation. Obviously this varies enormously with the time of day, with the latitude and with the season of the year.

The solar spectrum is limited at the short-wave end by the absorption band of ozone. This constituent of the atmosphere is about one hundred-millionth of the total volume of air at the earth's surface. It increases with altitude and reaches a maximum concentration at about 22 kilometers.[1] If all the ozone in the atmosphere were reduced to the volume it would occupy at normal temperature and pressure, it would constitute a layer only a few millimeters in thickness. However, the effectiveness of even this small amount of ozone in filtering out practically all of the solar energy shorter than about λ 2950 is very important to all life on earth.[2]

Another important factor in reducing solar ultraviolet energy in many regions of the United States is the great amount of cloudiness, especially in winter. Figs. 1 and 2 show the percentage of possible sunshine during winter and summer respectively, for the entire country.[3] Cleveland, Ohio, is in the Great Lakes cloud belt where the actual hours of winter sunshine are approximately 30 per cent. of the possible.

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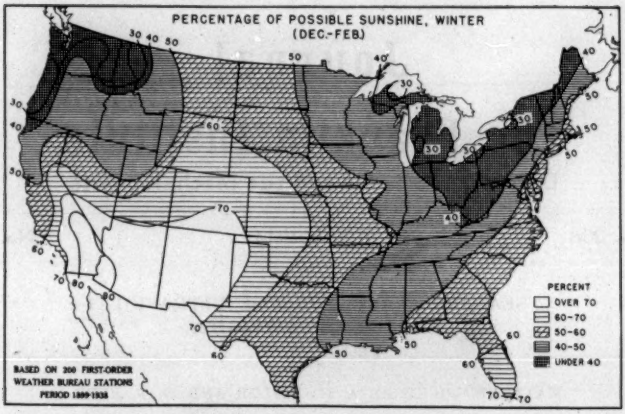

FIG. 1. From *Climate and Man*,[3] p. 738, U.S. Dept. of Agriculture for Year 1941.

Unless otherwise stated all our data were obtained in a suburb of Cleveland.

In Curve *A*, Fig. 3, is shown the relative tanning effectiveness of ultraviolet energy of different wavelengths as determined for the untanned skin of adult white subjects.[4] The maximum effectiveness is

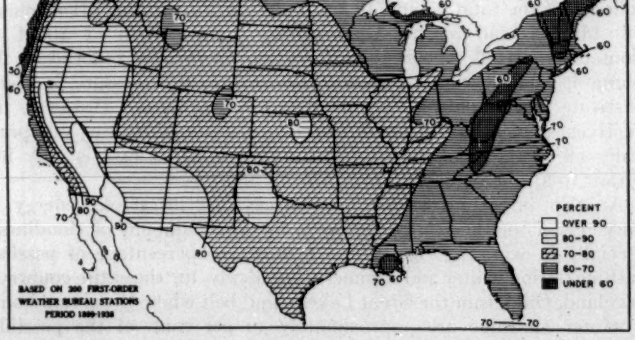

FIG. 2. From *Climate and Man*,[3] p. 739, U.S. Dept. of Agriculture for Year 1941.

at approximately λ 2967, which is close to the shortest wavelength detectable in midsummer sunlight in Cleveland or near sea-level anywhere. Curve *C* illustrates the spectral distribution of energy at the short-wave end of sunlight in July. The exact shape of the spectral anti-rachitic curve for human subjects is not definitely known, but such evidence as is available indicates that it is not markedly different from the erythemal and tanning effectiveness curve illustrated in *A*, Fig. 3. Consequently, changes in the short-wave end of the solar spectrum greatly affect the value of sunlight as an anti-rachitic agent.

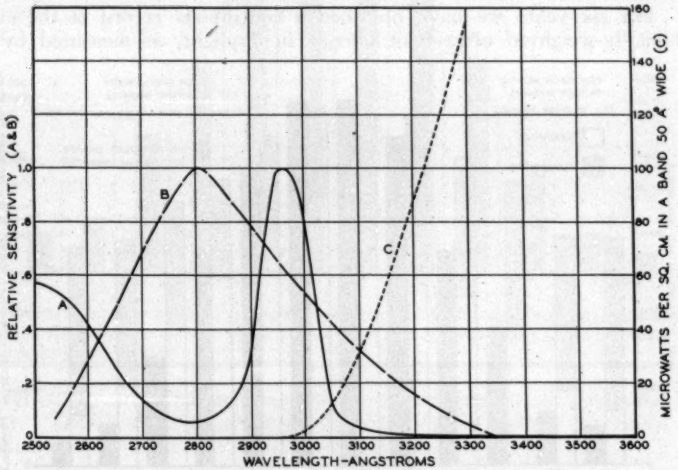

FIG. 3. (A) Relative tanning effectiveness of energy of various wavelengths.[4] (B) Relative spectral sensitivity of cadmium-magnesium alloy phototube. (C) Energy distribution of noon sunlight on July 12, 1938.

Erythema and tanning following exposure of the skin to sunlight or to an artificial source of ultraviolet energy, give visible evidence that the subject has received at least a minimum exposure to erythemally effective ultraviolet energy. Thus everyone is his own "ultraviolet meter," although the exposure required to produce a minimum perceptible erythema (*MPE*) varies over a considerable range with different individuals.

In our discussions of the ultraviolet for health purposes we have adopted as a unit of energy the *E-viton*[7]. This is equivalent to 10 microwatts of energy at λ 2967, where the relative erythemal effectiveness is a maximum (see Fig. 3A), or $10/E$ microwatts at any wavelength

having a relative erythemal effectiveness E. To produce a minimum perceptible erythema (MPE) on an average untanned skin requires an exposure of approximately 40 E-viton minutes per square centimeter of skin. Thus an MPE is produced by any one of the following exposures:

1 E-viton per square centimeter, acting for 40 minutes,
10 E-viton per square centimeter, acting for 4 minutes,
40 E-viton per square centimeter, acting for 1 minute.

We use this unit because it is so closely related to the biological reaction, sunburn, with which all are familiar.

For six years we have obtained a continuous record of the erythemally-weighted ultraviolet energy in daylight, as measured by a

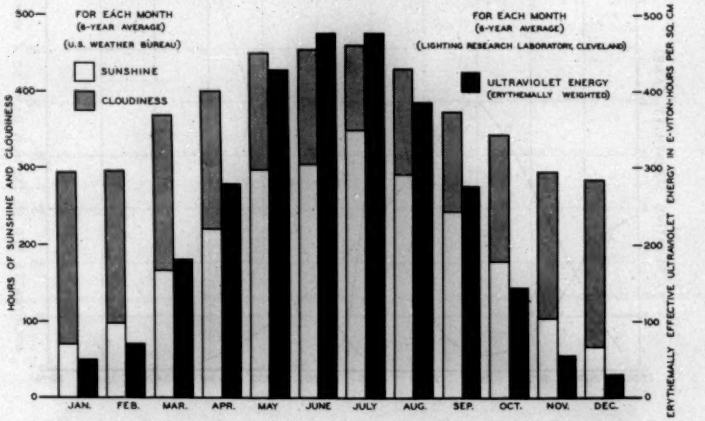

FIG. 4. Average monthly variations of erythemally-weighted ultraviolet energy for a continuous six-year period at Cleveland, Ohio. The monthly variations in hours of sunshine and in cloudiness are presented for the same locality.

cadmium-magnesium alloy phototube. Its spectral sensitivity is shown in Curve B, Fig. 3. This was used in an electronic integrator circuit[5, 6] in such a way that the integrated erythemal ultraviolet energy was recorded on a relay register. This was read and recorded at hourly intervals. The device was calibrated to measure the E-viton hours of energy on a horizontal plane which received the ultraviolet energy from the sun and from the entire unobstructed sky.

Records for six years have now been summarized and averaged to give a comprehensive picture of the seasonal variations, also of the effect of cloudiness in reducing the erythemal ultraviolet energy. In Fig. 4 the open and shaded columns show, respectively, the monthly

values of hours of sunshine and cloudiness throughout the year, averaged for the six years covered by the test. The black columns indicate the total amount of erythemally weighted ultraviolet energy received on a horizontal plane each month during the same period.

In Fig. 5 the hours of sunshine and the integrated erythemal ultra-

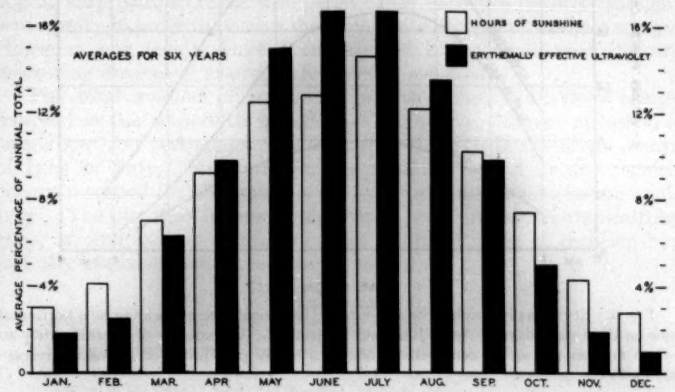

FIG. 5. Monthly variations in hours of sunshine and erythemally-weighted ultraviolet energy, expressed as percentages of the total for the year. These values are averages for a continuous six-year period.

violet energy are presented as monthly percentages of the totals for a year. These values are averages for the six-year period. In Table I some of the important facts are summarized.

TABLE I.

Erythemally-effective ultraviolet energy and hours of sunshine for three-month periods, expressed as percentages of the total for one year. These are averages for six consecutive years.

Three-Month Period	Per cent. of Average Annual Total	
	Ultraviolet Energy	Hours of Sunshine
Dec., Jan., Feb.	5.3	9.9
Mar., Apr., May	31.1	28.7
June, July, Aug.	46.9	39.5
Sept., Oct., Nov.	16.7	21.9

The intensity of erythemal ultraviolet energy in E-vitons per square centimeter, on a horizontal plane, is shown in Fig. 6 for three specific days in 1936. These curves show the decided seasonal variation as well as an hourly variation.

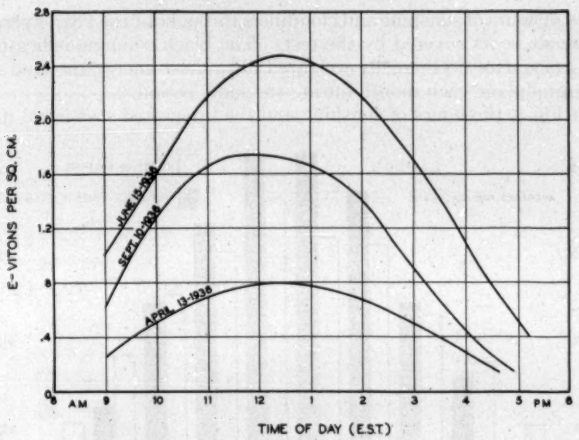

FIG. 6. Erythemally-weighted or anti-rachitic ultraviolet energy incident on a horizontal plane on three clear days in April, June and September. An exposure of approximately 40 E-viton minutes per square centimeter produces a barely perceptible erythema on average untanned skin.

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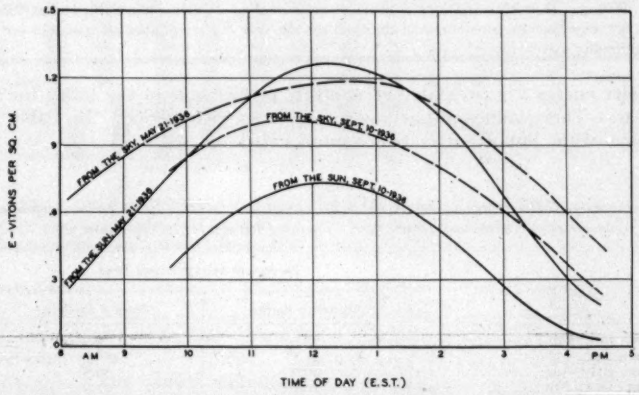

FIG. 7. Erythemally-weighted or anti-rachitic ultraviolet energy incident on a horizontal plane from the sun and from the entire sky on two clear days in May and September.

It is a very interesting fact that for about eight months of the year, a clear sky contributes more than half of the erythemal ultraviolet energy in daylight at all times of the day incident on a horizontal plane.

In the midsummer months there are only a few hours in the middle of the day when the erythemally-weighted ultraviolet energy from the sun on a horizontal plane exceeds that from the sky. This is clearly demonstrated by the curves in Fig. 7, showing the relative contributions by sun and sky on clear days in May and September. These facts may appear surprising to those who believe that exposure to direct sunlight is necessary in order to receive the beneficial effects of ultraviolet energy. However, our results have been checked many times with delicate measuring devices of appropriate spectral sensitivity.

The total amount of erythemal or anti-rachitic ultraviolet energy received in the six-month period from October to March, inclusive, is only about ten percent greater than that received in the single month of June or July. Furthermore, the total erythemal or anti-rachitic energy recorded for December is only one per cent. of that for the whole year. The use of solariums in the winter, with ultraviolet-transmitting glass, is obviously of limited or even doubtful value in securing biologically-effective ultraviolet energy indoors.

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Kilimanjaro: An Active Volcano.—Dr. P. E. KENT. (*Nature*, Vol. 153, No. 3885.) It is nearly a century since Kilimanjaro was discovered, a snow-capped mountain 200 miles south of the equator, and the highest point in Africa. Until recently it was thought to be quite extinct, but expeditions during the last few years have produced evidence of a recrudescence of activity in the broad Kibo crater which forms the more easterly of the twin summits. Parallel lines of fumaroles have been found associated with extensive beds of crystalline sulfur on the sides of the crater area. Emission of the sulfurous and acrid smelling gases was so copious that they could be detected a considerable distance away. The temperature of the fumaroles varied from 52° to 78° F. It was found that parts of the ground were warm and soft, so that the mountaineer frequently sank to his knees.

The presence of active volcanoes in East Africa makes one wonder whether there will ever be a recurrence of the great eruptions when enormous areas of the highlands were flooded with lava and covered with layers of volcanic ash. The active volcanoes occur in three widely separated areas: west of Kilimanjaro, the mountain of Doinyo Ngai has erupted at intervals during the last fifty years; far to the north in Kenya, Teleki's and Andrew's volcanoes at the southern end of Lake Rudolf have occasionally been active; and in Uganda, Nyamlagira of the active Mufumbiro group discharged a lava flow into Lake Kivu in 1938. In the intervening areas hot springs are known in many places, for example along the shores of Lakes Hannington, Magadi, Natron and Manyara (most commonly on the western slopes for some unepxlained reason), and steam jets at Eburru in the Njorowa gorge and in the volcanoes Longonot and Meru show that underground temperatures are still high over a wide area.

It is usually supposed that the localized activity of the volcanoes is a last dying glow, the remnant of the great eruptions which produced the plateau lavas. But there is much geological evidence to show that lavas were produced during two separate periods which were separated by a time quiescence probably as marked as that of the present day. There may, in fact, be a third upwelling of the lava from below over the highlands of East Africa. If there is, one can be sure that it will develop gradually and—if it happens at all—it is not to be expected until many centuries have passed.

R. H. O.

REMOTE AND AUTOMATIC ELECTRIC CONTROLS FOR AIRCRAFT.*

BY

WILLIAM P. LEAR,

President, Lear Avia, Inc., Piqua, Ohio.

The engineering developments of the past few decades have required the solution of numerous control problems concerning practically every branch of technology. Such a control problem appears whenever a certain physical quantity or condition is to be caused to vary in any prescribed manner, or is to be maintained substantially constant at a predetermined value or level.

A remote control is, in general, a means by which only very little initial effort is required to accomplish a control action at some distance away from the initiator. The initial effort may be applied manually, as by operating a switch or turning a dial, or may be applied automatically by means of an instrument or measuring device, capable of detecting variations of some physical quantity or condition (such as position, speed or temperature).

Usually very little force or power can be delivered by the measuring instrument itself and consequently additional power must be supplied from an auxiliary source by means of a servo-motor which performs the final control action. An electric actuator is essentially an electrically operated servo-motor with its associated gearing, arranged to deliver the force or power required for numerous control functions on aircraft.

An automatic control device by its very nature replaces a manual operation and, in many cases, the development of a control device is based upon the analysis of the manual operation which the automatic control is designed to replace. For instance, in the early stage of development of steam engines, the task of timing the periodic admission of steam to the cylinder was assigned to a boy who had to pull the rope at the right time while steam entered the cylinder. The invention of the drive of the slide valve from the eccentric eliminated the boy as a human control element, and considerably advanced the art of steam engines. Probably this was one of the earliest control problems solved satisfactorily in a very simple manner.

Very frequently a further development of a certain branch of technology is handicapped by the lack of an adequate control system. An illustration in this connection is the perennial problem—fascinating the minds of many inventors for more than half a century—the problem of

* Paper presented at the Joint Meeting of The Franklin Institute and The American Institute of Electrical Engineers, Philadelphia Section, March 29, 1944.

reducing the rolling of ships. It was known for many years that the disturbing torques exerted on a ship by wind and waves could be counteracted by means of fins, water ballast, moving weights, gyroscopes, etc. In fact, in the early Chinese paintings of the pre-Christian era, we find an indication that an attempt was made to solve this problem at that distant time. On these paintings are shown a sailing vessel carrying two men, one of them operating the rudder and the other holding the ropes attached to anti-rolling fins. In this case it took more than two thousand years to solve the problem and develop a suitable automatic control device to replace the second man.

APPARATUS TO BE CONTROLLED IN MODERN AIRCRAFT.

Early models of airplanes, or "flying machines," were controlled by direct mechanical connections from the pilot's control levers (or pedals) to the rudder, elevator, and other control surfaces. These small aircraft carried very few items of equipment or "accessories" which were not essential to flight, and were relatively simple to control, so that direct manual operation by the pilot was quite practical. Small, modern private aircraft similarly require only simple controls and few accessories for satisfactory operation.

As the size of aircraft increased, both for commercial and for military purposes, numerous accessories were added to improve the performance, safety and reliability, and to simplify the pilot's task of operating the airplane. In commerical planes, such accessories are needed for operation of retractable landing wheels, landing lights, and other projections which can be drawn inside the streamlined contour of the plane to reduce air resistance and permit high speed with maximum efficiency. Accessories are also needed for operating various flaps and shutters, such as wing flaps, engine cowl flaps, trim tabs and carburetor air intake shutters. In addition to accessories such as those just mentioned, military aircraft also require apparatus to operate bomb doors, bomb hoists, power turrets and other fighting equipment.

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METHODS OF OPERATING MODERN AIRCRAFT CONTROLS.

Direct manual operation of flying controls and accessories, by means of mechanical connections from the pilot's cockpit to the units to be controlled, is practically impossible in large aircraft, except where the mechanical linkages required are relatively short. Therefore, many remote control devices are required in these large planes. Also, in order to relieve the pilot of the necessity of continually manipulating controls to maintain the desired operating conditions, it is advisable to provide automatic controls where possible, so that the pilot can devote his entire attention to the maneuvering of the plane. Thus the problems of remote and automatic controls have beome more numerous as commercial and military aircraft have increased in size and speed.

By using remote and automatic controls, it is possible for the pilot and other members of the crew to operate a large plane with much less effort than would be required for direct mechanical control. These controls may be operated by means of any one of several forms of accessory power, such as hydraulic, electric, pneumatic, mechanical or a combination of these. The most commonly used accessory power systems in modern aircraft are the hydraulic or hydro-mechanical, the electric or electro-mechanical and combinations of the two, since, for some applications, a control operated by a combination of electric and hydraulic power still appears to be the most satisfactory solution to the problem.

Until recently, hydraulic motors had the advantage of lighter weight and greater smoothness of control. But manufacturers of electric accessories have now reduced the weight of electric motors and improved the control methods so that more and more of the larger aircraft are being equipped with electric control apparatus.

An electric power source has been essential in modern aircraft for operation of equipment such as lighting, intercommunication, radio communication and radio direction finding. The power ratings of aircraft electric generators are being continually increased to take care of more and more electrically operated actuators and controls, both of the direct-current and alternating-current types.

Electric circuits and motors, by their very nature, are especially well adapted to all kinds of remote positioning and automatic control. This is particularly true where electronic circuits may be used, since with them an infinitesimal amount of energy supplied to the grids of sturdy vacuum tubes is able to control an almost unlimited amount of energy available for supply to the control motors. Furthermore, the extraordinary adaptability of electronic circuits to all kinds of control functions was largely responsible for a rapid development of entirely new principles of controls which were known theoretically for a number of years, but could not be realized practically because of the lack of appropriate control means. Electron tubes with their associated circuits were the means of attaining a simple and elegant practical solution of these control problems which had previously been solved only theoretically.

As compared to hydraulic control systems, some other important advantages of electric control systems, especially for military aircraft, are more reliable operation at high altitudes and low temperatures, greater ease of installation and replacement of accessories, minimum fire hazard, and greatly reduced vulnerability to gunfire under combat conditions.

At the beginning of World War II there were comparatively few electro-mechanical installations in the then modern airplanes. However, with the increased amount of engineering time devoted to such

designs, more and more installations of this nature were made. Production airplanes were, in many cases, changed over, and new airplanes in nearly all cases were equipped with electro-mechanical control systems. The advantage of reduced vulnerability to gunfire hastened this change and the greater accessibility and serviceability as well as the ease of initial installations augmented the program. From the vulnerability viewpoint the electrical system, with the electric wires separated and freed from the previously conventional shielding conduit, offers less area susceptible to gunfire. The rupture of a wire by gunfire usually affects only one circuit, while the rupture of an hydraulic tube often affected an entire system or a major portion of a system. In addition, electrical systems can be powered by a multiplicity of wires going through the airplane by different routes, and thus have any one wire able to carry normal loads and the multiplicity in parallel to carry the peak load conditions.

AIRCRAFT ELECTRIC REMOTE CONTROL ACTUATORS AND RETRACTION UNITS.

Electro-mechanical units can be designed as complete packaged assemblies containing all of the switching controls, control mechanisms, and relays. This has resulted in simpler sub-assemblies, so that for installation it is only necessary to connect the driven mechanism and the standard electric connectors. Production of aircraft is facilitated, as all adjustments can be made beforehand. Also there is no bleeding of oil lines and no need for skilled mechanics having a general knowledge of the over-all assembly.

The increased demand for electro-mechanical systems has made it possible for some companies to specialize in the engineering development of such products and devote more time to engineering design, laboratory testing, development, proof testing, and field engineering than would be practical for any individual aircraft manufacturer. The result has been that these companies have been and are accumulating an engineering experience, design technique, and manufacturing ability exceeding that possible with any individual company using these products, such as an individual aircraft manufacturer. Such specialized accessory companies have, as a result, been doing engineering and design for the aircraft manufacturers.

These aircraft accessory manufacturers have found it to their own interest to try to standardize on certain designs. However, in many cases, try as they might, both the aircraft manufacturers and the accessory specialists have had to deviate from these standards. Certain basic component parts or sub-assemblies are standardized, so that they can be put together in a wide variety of combinations. This permits a great many variations to meet aircraft design conditions without new tooling or special development. Wherever possible, however, these minor variations are also being eliminated. The pressure of the war

has created a demand for quick deliveries and as a result many aircraft engineers have been willing to change the airplane design to use something that was already in production by an accessory company, changing the airplane rather than waiting for the accessory manufacturer to modify his product. In consequence it has developed that accessories of different airplanes are often completely interchangeable in the field, or at least have interchangeable basic parts.

Some examples of light-weight, electro-mechanical remote control actuators or retraction units now available for use in aircraft are illustrated in Figs. 1 and 2.

Figure 1 shows a cut-away model of a typical linear actuator for producing linear force. This actuator operates on the screw-jack

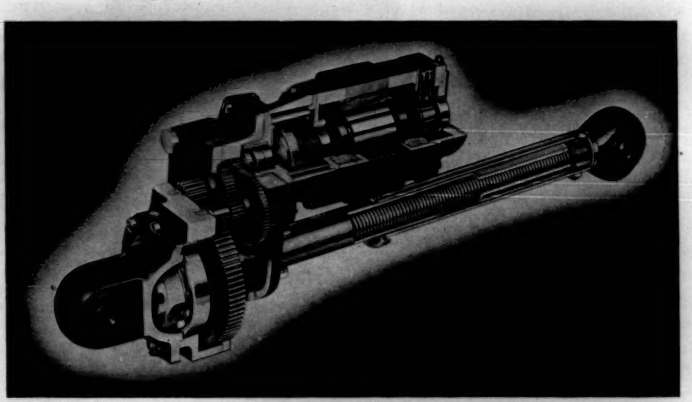

FIG. 1. Linear actuator, cut-away model.

principle and performs the same functions as a hydraulic retracting cylinder. The screw is revolved by a set of spur gears which are in turn driven by an electric motor.

Figure 2 shows in cut-away form a rotary actuator, which provides a source of torque or turning effort instead of linear force. The rotary output shaft is driven through spur gearing by means of an electric motor.

POSITIONING CONTROLS IN AIRCRAFT.

Several methods for remote control of electro-mechanical actuators or retraction units are available, depending upon the application in the aircraft.

The simplest method of control is a manual switch, which would generally be of the single-pole, double-throw type, controlling the direc-

tion of rotation of a split-field direct-current motor. This method permits stopping the unit at any intermediate position, and an electric telemeter (or position indicator) may be used to "repeat back" to the operator the position of the controlled device. Limit switches are normally incorporated in part of the gear mechanism and mounted on the gear box, as shown in Fig. 2. These switches break the motor circuit at either end of the normal travel of the actuator, and are adjusted in a jig at the accessory factory or on the bench before installation, to avoid the possibility of errors due to improper coordination between the switch adjustment and the driven mechanism.

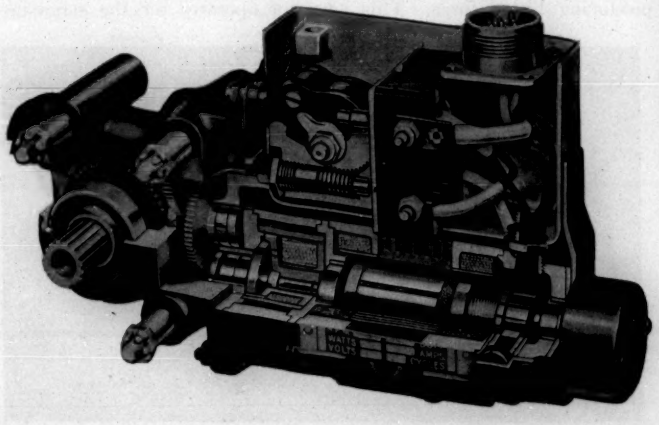

FIG. 2. Rotary actuator, cut-away model.

In some installations it is not possible precisely to predetermine the required travel of the driven device, and it is therefore not feasible to use limit switches. To achieve the desired result, it is practical to have the unit run against a shock absorber and then have the power shut off by means of an electrical or a mechanical overload device. In the electrical type the current overload due to the higher current to the motor actuates a relay, while in the mechanical overload type a torque-limiting device actuates a cut-off switch to stop the motor.

As electro-mechanicl systems are essentially mechanical systems with an electric power source, they offer many possibilities for mechanical emergency operation in case of electrical failure. Various basic arrangements have been designed. The simplest and most direct method in such event is to operate the unit manually by hand-crank or flexible cable. This is usually done by the use of flexible shafting which

turns at high speed and low torque. Another arrangement for emergency operation uses two or more electro-mechanicl power units interconnected mechanically. As applied to the "tricycle" type of aircraft landing gear, flexible shafting interconnects the two main wheel actuators and the nose wheel actuator, each having its own individual power unit. Thus, while one or two of the three motors may be inoperative, the remaining unit or units will operate the entire system through the mechanical interconnection. Also, the landing gear may be raised or lowered directly by means of a hand-crank in the mechanical interlock portion of the system.

ELECTRO-MAGNETIC "FASTOP" CLUTCH AND BRAKE.

Electro-mechanical systems have always been confronted with the problem of handling high inertia loads. Originally, it was almost impossible accurately to position an electro-mechanical device because of the variation in coasting and "overshooting" with varying external flight loads and flight conditions such as temperature, etc. Through the use of an electro-magnetic clutch to separate the high inertia parts from the low inertia parts of the device, accurate positioning is now possible. A simple electro-magnetic clutch fits on the motor between the armature and the first gear train, and the clutch-winding is connected electrically in series with the motor. Thus, the motor armature, with its high speed and consequent high inertia, can be automatically separated from the driven mechanism whenever the motor circuit is interrupted. By having the clutch located at the motor end of the gear train, the clutch can be of minimum size, since at this point the transmitted torque is low.

Referring again to Figs. 1 and 2, the clutch may be seen between the motor and the gear train of each of the cut-away models of the electric actuators illustrated. It may also be noted that the gear-driven mechanism, with its low speed and consequent low inertia, is stopped by a brake. Conventionally, the brake is applied by a spring which is overcome by magnetic force when the motor is energized.

This combination of electro-magnetic clutch with spring-applied brake is called the "Fastop" clutch and brake, and is shown diagrammatically in Figs. 3 and 4. The clutch and brake are shown in Fig. 3 in the de-energized position, with the drive and driven discs separated by the normal air gap of approximately 0.010 inch. The driven disc, which is fastened to the output shaft driving the load, is of solid magnetic material. The drive disc, which is fastened to the motor armature shaft, is also of solid metal, but the magnetic rim and center portions are separated by a ring of non-magnetic material. This allows the forming of magnetic poles on the drive disc when the motor current is turned on. The resultant magnetic force snaps the driven disc into contact with the drive disc.

The driven disc is held by the magnetic drive disc and both discs immediately revolve as a unit. Fig. 4 shows a cross-section view of the clutch in this energized position. A highly important feature of this clutch is that the magnetic flux is strong enough to hold the driven disc tightly against the drive disc, resulting in a frictional engagement sufficient to transmit the stall torque of the motor without slipping. This means that the clutch will not slip in normal operation. However if something jams, the clutch slips, thus providing a safety feature in the system to protect against breakage due to impact loads. For example, if the limit switch should fail to open the motor circuit, the motor would continue to run at high speed, driving the actuator to the end of its travel. Then the entire impact force due to the kinetic energy of the rotor would be transmitted into the system unless there

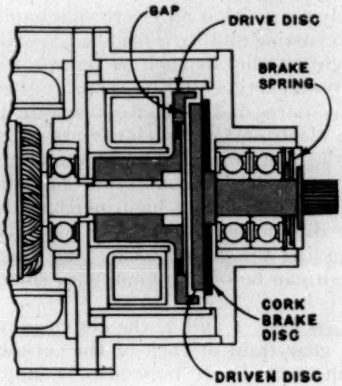

FIG. 3. "Fastop" clutch, cross-section, de-energized.

were some means of limiting the transmitted torque. The clutch provides this torque-limiting means by slipping at a torque slightly greater than the stall torque of the motor.

It may be interesting to consider for a moment the statement that the clutch will transmit the stall torque of the motor and yet that it also provides a means of protecting the driving mechanism from impact loads. When it is realized that the instantaneous torque due to the kinetic energy of the rotor can easily be many times the stall torque of the motor, it becomes apparent that a clutch capable of transmitting the stall torque of the motor can still provide protection of the system against impact loads.

Accurate positioning requires a means of stopping the pinion practically instantly when the motor circuit is opened. When the current

is turned off, the magnetic flux of the clutch collapses. The magnetic drive disc no longer attracts the driven disc to it. A spring fastened to the shaft of the driven disc pulls it away and snaps it back against a brake lining consisting of a ring of cork, as shown in Fig. 3. Thus the driven disc stops practically instantly.

In the arrangement just described, whenever the motor is not energized the brake is applied. This would impose an undue load in devices provided with means for manual emergency operation. To eliminate such difficulty, a second type of clutch-brake mechanism has been developed, in which the clutch is operated magnetically in the conventional manner to transmit the torque when the motor is ener-

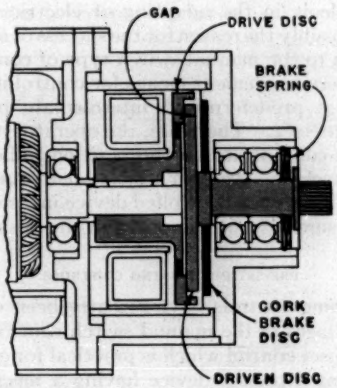

FIG. 4. "Fastop" clutch, cross-section, energized.

gized; but the braking action is furnished by centrifugal force when the motor circuit is opened. This combination of electro-magnetic clutch and centrifugal brake is called the "Rota-Brake."

The construction of the "Rota-Brake," not illustrated here, is similar to that of the "Fastop" clutch and brake, except that the brake spring is omitted and the center portion of the drive disc is hollowed out into an annular inclined plane. Several metal balls are placed against this plane. With the two discs attracted together, somewhat as in Fig. 4, and revolving at high speed, the centrifugal force on the metal balls tend to move them up the plane so as to separate the discs. However, the magnetic clutching force of the discs prevents this. When the motor circuit is opened, the clutch is de-energized. The centrifugal force on the metal balls is now unopposed and the balls move up the inclined plane against the driven disc, pressing it firmly against the

cork brake lining, giving an effect similar to that shown in Fig. 3. The motor output pinion, which is integral with the driven disc, is thus stopped practically instantly, while the motor armature, due to its inertia, continues to revolve. Above a predetermined value of speed the metal balls not only continue pressing against the driven disc but also function as a thrust bearing. The braking force remains on the driven disc until the speed of the motor armature has decreased to a predetermined value. The balls thereupon drop back into the annular recess, and the driven disc is again free to rotate. Thus no braking drag remains on the driven disc to retard possible manual operation of the actuator system.

The "Fastop" clutch and brake and the "Rota-Brake" have solved a multitude of problems in the adapting of electric motors to aircraft controls, and are possibly the reason for the success of electrical actuation.

Referring again to the manual switch type of control, it is apparent that this is not a very convenient means for controlling actuators which must be stopped at predetermined intermediate positions, since the control cannot be pre-set. Therefore, the operator must keep his hand on the switch and concentrate on the position indicator until the desired position is reached. Another objection to the manual switch is that it is difficult to move the controlled device in "steps" or increments small enough to insure accurate stopping in the desired position.

V. 19

PRE-SET POSITIONING CONTROLS.

Pre-set positioning controls have recently been developed to overcome the disadvantages of the manual switch control.

One type of pre-set control which is practical for certain applications is a remotely-operated pre-set device having a mechanical connection between the controlled aircraft component and the cockpit control. In this system, the pilot operates a control knob which closes an electric contact, causing the actuator motor to be energized for rotation as required to move the aircraft component in the proper direction to the new desired position. A flexible cable, leading back from the aircraft component to the cockpit, opens the contact and de-energizes the motor when the desired position is reached. This cable also moves a position indicator in the cockpit, showing the position of the controlled component. In some devices of this nature it has been possible in an emergency to operate a driven mechanism through the flexible cable from the position-indicating control in the cockpit. This has been suitable for tab controls and similar lightly loaded units. However, on very large aircraft it is not practical to utilize such flexible cables.

For completely electrical remote positioning, it is possible to use a simple direct-current "bridge" circuit, in which two "potentiometers," or voltage dividers, are connected in parallel across the d-c power source

and the coil of a sensitive polarized or directional relay is connected to the movable contact arms or "sliders" of the potentiometers.

Figure 5 is a schematic electrical diagram of such a positioning control circuit. As shown here, the directional relay controls a reversible split-field direct-current motor with series-field windings F_1 and F_2. In this system, the transmitter or control potentiometer P_T is located in the cockpit, while the receiver or position reference potentiometer P_R is geared to the actuator motor. When the pilot moves the slider of transmitter potentiometer P_T to a new position, and thereby unbalances the bridge circuit, the resulting "signal" voltage applied to the coil of the directional relay causes one set of its contacts to close. These contacts then control the energization of the d-c motor, causing it to rotate (clockwise or counterclockwise) as required to move the

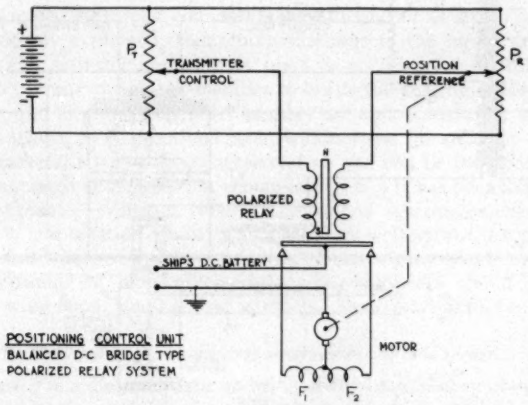

FIG. 5.

actuator and the controlled aircraft member to the desired new position, corresponding to the pilot's setting of the transmitter control P_T. The broken line connecting the motor and position reference potentiometer P_R represents the gearing which causes the motion of the slider of this potentiometer to be proportional to that of the controlled aircraft member, and therefore when the latter reaches the desired position, the slider of potentiometer P_R matches the pilot's setting of P_T. The bridge is again balanced so that no further control signal voltage is applied to the coil of the directional relay, thus allowing its contacts to reopen. The motor is thereupon de-energized and the actuator remains in its new position.

Unless the relay is made exceptionally sensitive, the system shown

in Fig. 5 is subject to positioning errors of the order of ±2 per cent. to ±3 per cent. of the total travel of the driven device. It is difficult in such a system to provide for anti-hunt or stabilizing means in the electric motor control. Thus, due to the inertia of the motor, the speed of operation of the controlled member has to be limited and the width of the "null" or "backlash" zone must be considerably wider than is necessary in a system that may incorporate a proper degree of "anticipation."

To avoid using an extremely sensitive and delicate relay on an aircraft to obtain higher positioning accuracy, and also to provide absolute stability and anti-hunt features, an electronic control circuit has been developed in which the sensitive relay is replaced by a rugged vacuum tube and differential relay combination.

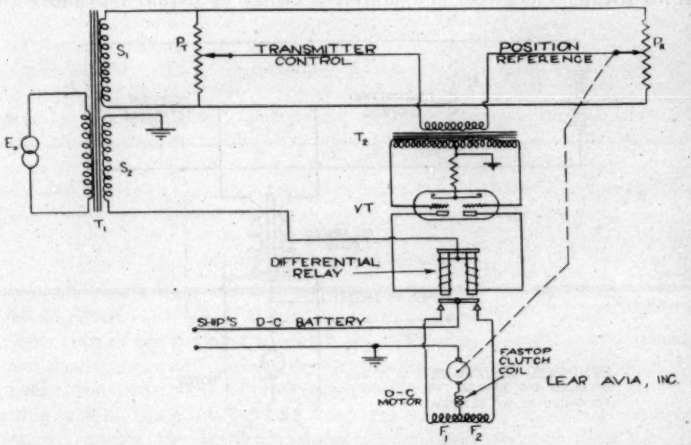

FIG. 6.

Figure 6 shows a schematic diagram of a positioning control circuit using the electronic tube—relay system with a balanced alternating-current bridge connected to the secondary S_1 of power transformer T_1. In this circuit the sliders of potentiometers P_T and P_R are connected to the primary of the grid transformer T_2, which "steps up" the weak signal voltage before it is applied to the grids of the vacuum tube, VT. The differential relay coils, which are connected respectively in series with the plates of the tube, receive their power from the secondary S_2 of the power transformer. When the bridge circuit is balanced, there is no a-c signal to the grids of the tube, and the relay coil currents are balanced. The relay contacts are open and the motor de-energized.

When the pilot moves the slider of transmitter potentiometer P_T to a new position, the tube amplifies and rectifies the resulting unbalanced signal voltage, causing one relay coil current to increase and the other to decrease. The relay operates to energize the actuator motor which then moves the driven aircraft component, and with it the slider of position reference potentiometer P_R, to the position corresponding to that of the transmitter potentiometer P_T. The bridge circuit is again balanced so that no further control signal voltage is applied to the grids of the vacuum tube VT, and the relay coil currents return to their balanced values, allowing the relay to open and stop the actuator in its new position.

An important feature in stabilizing the operation of this control system is the use of a fast-acting, low-inertia clutch. One such clutch that has proved satisfactory in actual service is the "Fastop" clutch which is in electric circuit connection with the motor as shown in Fig. 6. As previously explained, this clutch disconnects the motor from the gearing and actuator immediately upon de-energization of the motor, and also permits the clutch member to brake the gearing, whereby the actuator and airplane controlled member are almost instantly stopped. Other features, to be described later, will increase the stability or anti-hunt characteristics of the control system and can be incorporated in an arrangement similar to that shown in Fig. 6. It has been found that a potentiometer—vacuum tube—relay control system, as exemplified by Fig. 6, can position remotely to accuracies well within ± 1 per cent. of the total travel of the driven device. Such accuracies are ample for the positioning of most accessories and components on an aircraft, such as wing flaps, landing gear, shutters, doors, cowl flaps, etc.

ANALYSIS OF A-C BRIDGE TYPE POSITIONING CONTROL SIGNAL.

Figure 7 is a diagrammatic showing of the basic theory of operation of the system shown in Fig. 6, and illustrates how two parallel-connected potentiometers P_T and P_R represent a Wheatstone bridge. The relative values of the resistances of the four branches of the bridge are determined by the settings of the sliders of the transmitter control and position reference potentiometers. Thus the voltage v_T is determined by the pilot's setting of the transmitter control, and hence corresponds to the desired position of the aircraft component controlled by the actuator. Similarly, the voltage v_R corresponds to the actual position of the controlled aircraft component. The bridge circuit is balanced when the sliders of potentiometers P_T and P_R are in corresponding positions so that the voltages v_T and v_R are equal. Movement of the transmitter potentiometer slider causes a voltage unbalance in the bridge and applies a control signal voltage v, which is the difference between v_T and v_R, across the primary of grid transformer T_2. This

signal voltage is stepped up by the transformer and applied to the grids of the vacuum tube through the secondaries S_3 and S_4.

Curve (B) at the left of Fig. 7 shows the conditions when the transmitter position voltage v_T is increased in magnitude over the receiver position voltage v_R, as indicated on the diagram. These voltages are in phase and their resultant (difference) is the control signal voltage v, which is shown in Curve (C) at the left, in phase with the supply reference voltage E_0.

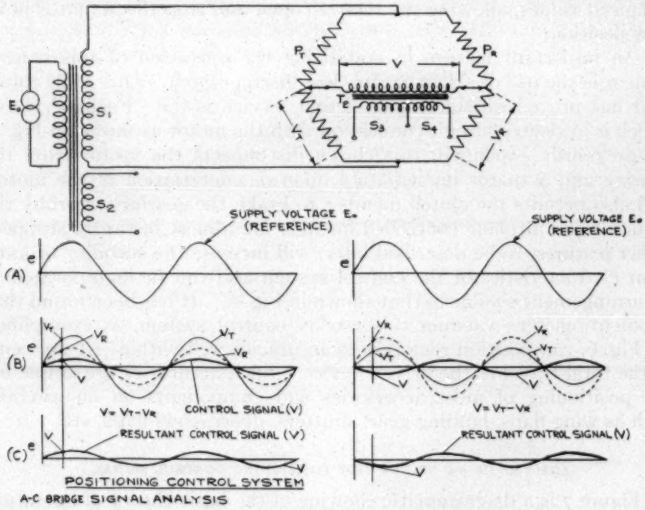

FIG. 7. Diagrams used for analysis of control signal in a-c bridge type positioning control system.

Similarly, the curves at the right of Fig. 7 indicate the conditions when the transmitter position voltage v_T is less than the receiver position voltage v_R. In this case, the resultant control signal voltage v is 180 degrees out of phase with the supply reference voltage E_0, and hence 180 degrees out of phase with the previously described signal voltage shown in Curve (C) at the left. The control signal voltage combines either in phase or 180 degrees out of phase with the reference voltage supplied to the anodes or plates of the vacuum tube, and thereby controls the selective operation of the differential relay.

The next diagram, Fig. 8, shows schematically the circuit of a practical and modern electrical remote positioning control system.

"Autosyn" or "Selsyn" type units are used in this circuit to generate the control signal voltage. The rotor of the transmitter Selsyn unit A is controlled by the pilot through a knob, dial, lever, or the like. The rotor of receiver Selsyn unit B, in which the control signal voltage is produced, is connected to the control grids of vacuum tube VT through a step-up transformer T_2. This control voltage, applied to the grids of the vacuum tube VT, is produced as a result of a relative angular displacement between the rotors of Selsyn units A and B and, depending upon the direction of the angular displacement, is either in phase or

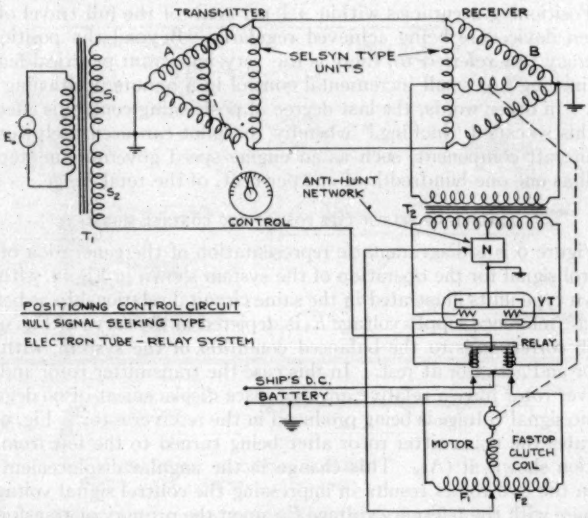

FIG. 8.

180 degrees out of phase with the reference voltage E_0. In other words, the control signal causes the vacuum tube and the differential relay to operate in a manner similar to that just described in connection with the a-c bridge control system. However, greater positioning accuracy is possible with the use of the Selsyn type units. The voltage E_0, which energizes the system, is obtained from a local a-c power source, which may be an electronic oscillator, a vibrator unit, or an inverter operated from the ship's storage battery. The actuator motor is a d-c unit which is energized by the ship's battery only when control action is taking place. There is no stand-by motor current to raise the ambient temperature of the motor or waste the electric supply energy of the plane.

The anti-hunt network indicated at N in Fig. 8 is an important feature in such a control system. Such networks really are simple combinations of resistors and condensers connected into the circuit to give "anticipatory" signal effects to prevent hunting of the motor. Such anticipation amounts to the introduction of signal effects on the grids of the vacuum tube VT, which are a function of the control signal and the electrical operation of the motor. Here again the Fastop clutch in circuit connection with the motor, together with the anti-hunt network, affords a system that will not overshoot, but merely comes rapidly to its new position and stops.

Positioning accuracies within $\pm\frac{1}{4}$ per cent. of the full travel of the driven device are being achieved regularly. Beyond the positioning accuracy just referred to, there is the very important practical feature of "inching" or small incremental control in a remote positioning system. In other words, the last degree of positioning control is effective by this so-called "inching," whereby the pilot can accurately control an aircraft component, such as an engine speed governor, in steps as small as one one-hundredth of one per cent. of the total range.

ANALYSIS OF SELSYN TYPE POSITIONING CONTROL SIGNAL.

Figure 9 is a diagrammatic representation of the generation of the control signal for the operation of the system shown in Fig. 8, with the Selsyn type units illustrated in the same circuital relationship as before. The a-c reference supply voltage E_0 is depicted in the curve of Fig. 9(A), which corresponds to the balanced condition of the system, with the motor and actuator at rest. In this case the transmitter rotor and the receiver rotor have a relative angular space displacement of 90 degrees, and no signal voltage is being produced in the receiver rotor. Fig. 9 (B) indicates the transmitter rotor after being turned to the left from the position shown at (A). This change in the angular displacement between the two rotors results in impressing the control signal voltage v, in phase with the reference voltage E_0, upon the primary of transformer T_2. Conversely, when the transmitter rotor is turned in the opposite direction from its neutral or null position, the control signal voltage v generated is 180 degrees out of phase with the reference voltage E_0, and hence 180 degrees out of phase with the preceding control signal. Thus a selective control of the vacuum tube VT and the differential relay is effected.

In discussing electrical positioning systems, the terms "positioning accuracies" and also "incremental controlling" are used. A positioning accuracy within ± 1 per cent. represents a "null zone" or "dead zone" having a width of 2 per cent. of the total travel of the controlled member. This corresponds to the amount of "backlash" in mechanical and hydraulic control systems. Thus the null signal or dead zone region in electrical systems, within which any control signal voltage does not

operate the relay or motor, represents the backlash. By suitable design and selection of components the backlash in electrical systems, as already stated, can be refined down to the order of a full width of less than ½ per cent. It is the writer's experience that electronic positioning controls can be designed with less backlash than can mechanical or hydraulic systems, and that they also provide superior "inching" or incremental controlling, especially where the distance between the control and the actuator is great.

The electronic tube—relay controller systems are sometimes referred to as "discontinuous controllers" in contradistinction to the so-called

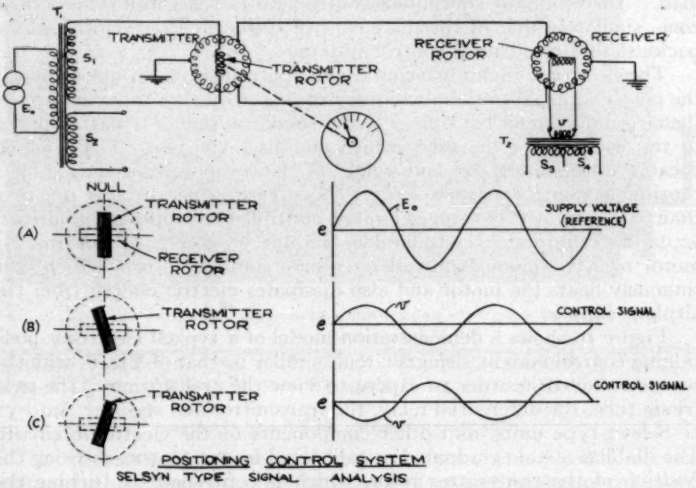

FIG. 9. Diagrams used for analysis of control signal in Selsyn type positioning control system.

"continuous controllers." A continuous controller does not have a relay, but the motor is energized directly from the a-c power supply through the vacuum tube control circuit. A typical continuous control system uses the same method as in Fig. 8 for the generation of the control signal voltage, but the relay is replaced by two saturable core reactors and the motor is a two-phase induction motor. The control signal voltage, as heretofore, selectively energizes either section of the twin vacuum tube VT and thus selectively controls the saturation of the reactors, thereby controlling the magnitude and phase of the voltage impressed on the control winding of the motor. The other winding of the motor is continuously energized by the a-c source voltage E_0, and

a capacitor is inserted in this circuit to give the phase displacement required for proper operation of the motor.

The amount of torque developed by a two-phase motor depends upon the magnitude of the control signal voltage, or the amount of control current passing through the control winding, thus giving the effect of "springiness" in a continuous control system. This is particularly true near the null or standstill position where the forces on the rotor of the motor are weakest. Accordingly, a small displacement of the transmitter controller from the null position results in a motor torque too weak to overcome the friction of the motor and the driven load. Therefore, the continuous controller also has a null zone or dead zone, similar to that of the relay control system, corresponding to the backlash of a mechanical control system.

The electronic circuit of a continuous controller must control directly the power supplied to the a-c motor winding, while in a relay controller the electronic circuit controls only the small fraction of a watt supplied to the windings of the relay which energizes the motor. Therefore, because of the larger size and weight of the components required for a continuous controller, such a control system is generally less practical than the simple tube—rugged relay controller for operating aircraft actuators requiring a considerable amount of power. Also, the a-c motor of a continuous controller requires stand-by power which continuously heats the motor and also dissipates electric energy from the airplane supply.

Figure 10 shows a demonstration model of a typical electronic positioning control system, using a circuit similar to that of Fig. 8, with the covers removed in order to expose to view the transformers, the twin triode tube, the differential relay, the transmitter and receiver Autosyn or Selsyn type units, and other components of the electronic circuit. The dial has a scale graduated or calibrated from 0 to 100, showing the position of the transmitter rotor, which is controlled by turning the knob. The linear scale, also calibrated from 0 to 100, shows the position of the screw jack of the linear actuator. In actual operation, the linear actuator quickly follows any change in setting of the control dial, and comes to rest in the new position with the dial readings corresponding within $\frac{1}{2}$ per cent. of the full travel of the actuator.

A rugged but sensitive differential relay with built-in snap action switches has been developed for use in the electronic positioning control system just described. This relay can safely interrupt currents of relatively high value, so that the large actuators such as those shown in Figs. 1 and 2, can be controlled with the electronic circuit using only a single twin triode tube.

It should be noted that these remote pre-set positioning controls are all intermittent duty devices, so that the commutation of the electric motors is not so serious a problem as would be encountered in continu-

ous duty motors. The greatest difficulty with commutation occurs in motors operating continuously at high altitudes; but the intermittent duty actuators have a relatively small accumulated time at high altitudes. This is only one of the factors contributing to the reliability and

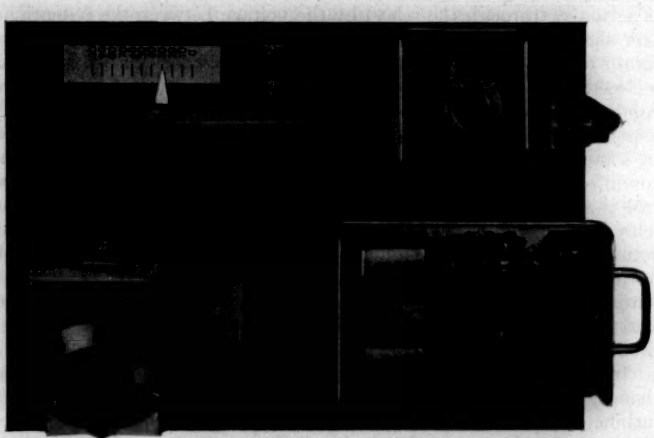

FIG. 10. "Leartron" positioning control system, demonstration model.

long operating life of electric remote control actuators, and the applications of these actuators in modern aircraft are increasing very rapidly.

GENERAL THEORY OF AUTOMATIC CONTROLS.

The theoretical analysis of servo-mechanisms as applied in electric remote and automatic controls has been well covered in papers published by Hazen,[1] Minorsky,[2] and others, in technical journals such as those of the Franklin Institute and the A. I. E. E. Thus no attempt will be made to cover the mathematical analysis at this time. However, a brief statement of the fundamental principles involved seems worthwhile. If one analyzes any remote or automatic control, one discovers always the same situation. It is desired to establish and maintain a definite state, or level, of a certain physical quantity or condition, such as the position of the aircraft landing gear, or the voltage of the generator, or the speed of the propeller, or the temperature of the engine, or the rate of flow of a liquid or gas, or the course of a ship or plane steered

[1] Hazen, H. L.: "Theory of Servo-Mechanisms," *Journal of The Franklin Institute*, 218, No. 3, Sept. 1934, pp. 279–331.

[2] Minorsky, N.: "Control Problems," *Journal of The Franklin Institute*, 232, No. 5, Nov. 1941, pp. 451–487; and 232, No. 6, Dec. 1941, pp. 519–551.

automatically, etc. The controls discussed here are of the "closed-cycle" type so that the control is actuated by a quantity or "signal" which is in turn affected by the control operation. For example, in the simple bridge circuit relay control previously described, the motor is actuated (through the relay) by the voltage between the potentiometer sliders, which voltage is in turn reduced to zero as the controlled motor returns the potentiometers to the balanced position. In general, a closed cycle control for establishing or maintaining a definite physical condition requires the use of a "servo-mechanism" which is essentially a power-amplifying or torque-amplifying device operated or actuated by some function of the difference between the desired condition and the condition actually existing. For example, the bridge circuit relay control is a simple servo-mechanism in which the voltage applied to the relay is a function of the difference between the desired position and the actual position of the controlled actuator. In this case the very small torque exerted by the pilot in turning the transmitter, or control potentiometer, is amplified by the relay and motor to drive the actuator load and the receiver, or position reference potentiometer, to the desired position.

In an automatic control system, the disturbing factors, such as changes of the load on a generator, the resisting torque on the shaft of a turbine or propeller, the temperature of the air surrounding an engine, or the wind acting on a plane or ship—all these factors cause unpredictable disturbances, tending to displace the system from its predetermined level or state. The purpose of the automatic control scheme is always the same: to release the operation of a certain auxiliary power system so as to counteract the effect of the disturbance and bring the system back to its set level.

We can go further in our analysis and visualize the following chain of the cause-effect relationships characterizing any closed-cycle control system. First, there is the system (1) to be controlled. Then there is the detector (2) of the error, or departure from the set level or desired value. After this comes the control system proper (3), which establishes a certain predetermined functional relationship between the signal from the detector and a certain control action. This action is used, ultimately, for the purpose of releasing a certain amount of energy, or force, from an auxiliary source of power (4), and this energy, or force, is applied to (1) in such a manner as to reduce the error or departure to zero. It is thus seen that any control process is always characterized by a closed chain or cycle (1)—(2)—(3)—(4)—(1) of the cause-effect relationships.

Thus, for example, in the problem of the automatic steering of a ship, the element (1) is the ship to be steered, (2) is the compass registering the departure from the set course, (3) is the control system establishing a certain predetermined relation between the departure from the

course and the displacement of the valve of the steering engine, while (4) is the auxiliary source of power consisting of the steering engine-rudder combination. Any other automatic control system can be analyzed in similar terms.

From this analysis, it appears that a control device cannot operate before the departure or error has appeared in the detector. The word "anticipatory" frequently used in connection with control systems is, therefore, to some extent, misleading. No device can actually "anticipate" the occurrence of a disturbance, but it can anticipate its undesirable effect by starting the controlling action early enough and in such a manner as to limit the magnitude of the effect, that is the departure, to an admissible value.

If we now turn our attention to the quantitative character of a control process, we discover that the properties of a control system cannot be established per se, but have to be subordinated to the properties of the system to be controlled. Consider, for example, the same problem of automatic steering, and let us inquire whether the same control system will perform equally well in steering a small yacht and a large transatlantic liner. Before answering this question, let us consider the process of the manual steering which will give practical indications to our analysis. We know from our experience that almost anyone can steer a small yacht merely by looking at the compass card and by operating the steering wheel so as to keep the lubber line of the compass on the set course. We do not experience any difficulty in this connection. If, however, we attempt to steer a large liner by following this method, we readily discover that we cannot steer the ship in this manner. In fact, the ship will start yawing over very large angles, possibly 10 degrees or more, and this yawing, or oscillating from one side to the other side of the set course, will be maintained indefinitely. We may inquire how a good helmsman operates the rudder of a large ship. Initially, as soon as the deviation from the course has been observed, he does exactly the same thing as a man steering a yacht does; that is, he begins to move the rudder. The difference between the two modes of steering comes only a moment later. It would be certainly poor judgment on the part of the helmsman of a liner to "keep the rudder on" until the lubber line on the compass comes back to the set course, since in such a case, the ship will "overshoot" the mark and poor steering will result. What a good helmsman does is "to ease the rudder off" as soon as he has noticed that the ship is responding to its rudder; that is, as soon as he notices the appearance of angular velocity of the ship toward its set course. Thus, in addition to watching the departure, a good helmsman is watching also the state of angular velocity of yawing. This renders the manual steering of a large ship more difficult than that of a small one, because the helmsman has to watch two factors: the

departure of the ship from her course and also its rate, instead of the departure only, which is sufficient for steering a small vessel.

HISTORICAL USE OF HIGHER DERIVATIVES IN CONTROLS.

The analysis of the manual steering, which led eventually to the evolution of the automatic steering control system is particularly interesting because, historically, this particular development gave rise to the appearance of modern control systems based on the principle of higher derivatives of the departure as the means of control. This principle can be best established mathematically, but we shall not enter into this matter here.

It is possible, however, to give a fuller account of these modern trends in the science of controls by further analysis of our example. If, in addition to observing the angular velocity (which, speaking mathematically, is the first derivative of the departure), the helmsman were able to perceive also the rate at which the angular velocity varies; that is, whether it decreases, or increases, or remains stationary, he might time the "easing off" action still more accurately. Here, however, we reach a limit of the sensitivity of the human judgment in analyzing visually the slow motion of yawing on a large ship. In other words, the eye of the helmsman is able to detect the angular velocity of yawing, but is unable to determine its rate of change—the angular acceleration, or the second derivative of the departure. The human detector is, therefore, not sufficiently sensitive for this purpose, and one has to rely on mechanical, or still better, electrical detectors in order to be able to go further in that direction. The confirmation of these theoretical conclusions was first made in 1922 by Dr. N. Minorsky [3] on a ship of 32,000 tons. In the first experiment with the departure control from a compass, the ship entered into a sustained yawing of about 15 degrees abouts its set course. In the second test, in which the angular velocity control was added to the departure control, the automatic steering device was able to maintain the course of the ship within the limits of about ± 1.5 degrees. This result was already comparable to what an average helmsman can accomplish. In the third test in which the angular acceleration control was added, the course of the ship was maintained within the limits of about $\pm \frac{1}{4}$ degree, that is, far more accurately than what a most experienced helmsman can accomplish under the most favorable conditions.

During the two decades which followed these experiments, the application of this principle of a control action responsive to higher derivatives of the departure of the system from its predetermined level or state, became universally adopted in every branch of control prob-

[3] Minorsky, N.: "Automatic Steering Tests," *Journal of the Society of Naval Engineers*, 42, No. 2, May 1930, pp. 285–310.

lems with a practically limitless degree of accuracy. Control of speed, of flow, of temperature, or angular motion of ships and aircraft, training of guns of naval vessels, training of anti-aircraft guns, adjustment of the pitch of propellers on airplanes, ultra accurate control of speed of huge motors in industrial applications, special drives in which either the speed or a difference of speeds of two distant motors has to be maintained within very narrow limits—all these applications became possible owing to this principle of anticipatory action by higher derivatives.

AUTOMATIC CONTROLS ABOARD MODERN AIRCRAFT.

A proper understanding of the functioning and effects of automatic controls aboard an aircraft would involve a description of many specialized aircraft components and requirements. Space limitations and the demands of military secrecy do not permit such a description here; but a brief reference will be made to the ever-increasing number of such automatic controls that are at the present day actually functioning aboard our war and commercial aircraft. Examples of these are included in the following list:

1. Automatic engine temperature controls.
2. Automatic intercooler shutter and exit door controls.
3. Automatic oil cooler shutter and exit door controls.
4. Automatic exit flap door controls for air-cooled engines.
5. Automatic anti-icer heat exchanger controls.
6. Automatic engine speed controls.
7. Automatic engine power controls.
8. Automatic cabin air temperature controls.
9. Automatic cabin air pressure controls.
10. Automatic controls in accordance with altitude.
11. Automatic turbo-supercharger controls.
12. Automatic engine synchronizer controls.
13. Automatic radio direction finders.
14. Automatic pilots.

Some of the automatic controls in this list are in the flight-test stage of development for use in the larger aircraft, and, since they are still in the realm of military secrecy, their details obviously cannot be even mentioned here. However, as typical examples of aircraft automatic controls, it is permissible at this time briefly to describe some of the engine temperature control systems now in use.

Figure 11 shows a flight test model of an electronic automatic temperature control system. Such a system is more sensitive to temperature variation and can hold temperatures to within closer limits than the liquid bulb type just described. Here shown is a linear actuator unit which directly controls shutter doors for temperature regulation. Also shown is a single-tube electronic chassis which is a circuit controller

corresponding to the "Leartron" type circuits previously discussed in connection with the electric positioning control systems. At the upper right corner of this photograph is shown a relay control box and inverter which controls the motor of the actuator and energizes the electronic circuit. By means of switches on the control panel, shown in the upper center of the photograph, the pilot can select the range within which he desires to control the temperature of the engine or coolant.

The thermo-sensitive element used with this system is made of a specially sensitive material having a high negative temperature coefficient of resistance, and it is fitted into the tip of an adapter unit which

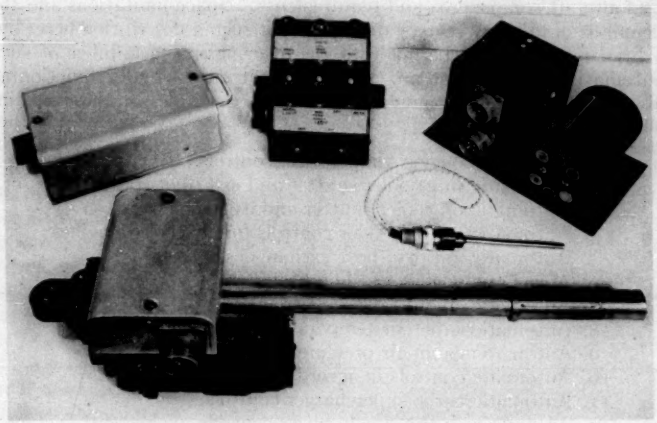

FIG. 11. Flight test model of electronic automatic temperature control system.

may be seen in the photograph. This unit is inserted into a small well of the cylinder of the engine or in any other portion of the airplane, the temperature of which is to be determined and controlled.

Temperature variations in an engine can be kept to within a range of the order of 5° Centigrade if desired. Such small variation is very very important in liquid-cooled engines. For air-cooled engines, a controlling temperature range or "modulating range" of about 25 degress is practical and quite feasible with this type of system.

A typical installation of an engine temperature controlling system, such as that just described, is illustrated in Fig. 12. This shows the complete cowl flap assembly with one rotary actuator, of the type shown in Fig. 2, operating eight screw jacks which are interconnected by

flexible shafting. These screw jacks control the position of the cowl flaps surrounding the engine to maintain the temperature within the desired limits. The flaps are shown at A in the closed position and at B in an open position.

Numerous positioning controls and automatic controls, such as those mentioned and described here, are relieving the pilot, co-pilot, navigator and other members of the crew of a modern aircraft from previous onerous and difficult tasks, so that they may concentrate on more important duties. We have heard of war planes being damaged by flak and bullets to a stage where it was deemed impossible to continue flight, and yet such planes returned safely with their major functions effective. The accelerated development in aircraft controls, both manual and automatic, has been, of course, enhanced by the war and the requirements of battle service. Scores of groups of industrial and university scientists, engineers and physicists have been concentrating on such problems to the benefit of the American and Allied war effort. The resulting achievements and advances will remain with us when this war ends, to render the flight of man more comfortable, safe, and swift.

CONCLUSIONS.

Referring again to the general theory of automatic controls, one may question now whether the problem of controls has not reached a stage beyond which it is useless to proceed any further. Unfortunately, as in any other development, a point is reached when new problems arise as the result of extending the range too far or as additional requirements appear. A similar situation arose in the modern science of the radio. The original optimism when the transmission was limited to relatively short distances gave way to disappointments when the range of transmission was considerably increased. The questions of static, of reflection of waves from the Heaviside layer, etc., appeared as serious handicaps toward a further progress. Attention of later inventors was turned toward these various problems and required further improvements, such as all kinds of anti-parasitic circuits, frequency modulation, etc. The science of modern controls did not escape this situation either.

As the accuracy and sensitivity of the control systems increase, they become more and more affected by the parasitic effects which are amplified also together with the useful control signal. These parasitic effects, particularly on board moving bodies such as ships and airplanes, result from the vibration of supports due to many types of machinery on board. The control which utilizes the derivatives of the departure amplifies these parasitic phenomena owing to their relatively high frequency and, under certain conditions, they may cause the blurring of the useful control signal. No doubt, all these problems will eventually be solved and their solutions have in many instances already been

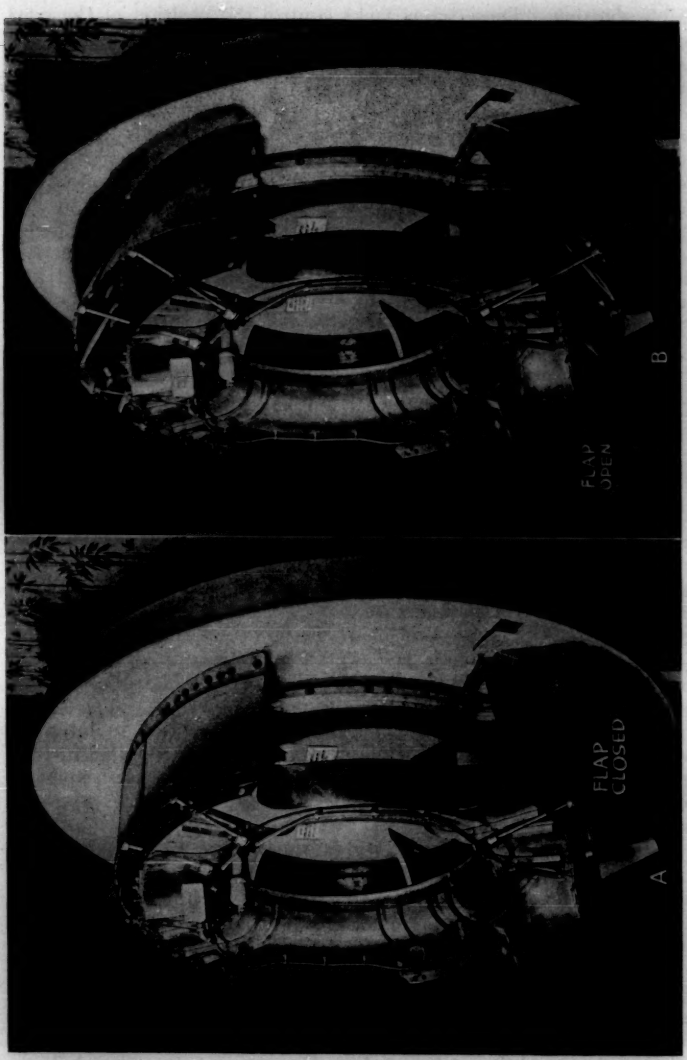

FIG. 12. Typical installation of engine temperature control system.

effected; but it would be an exaggeration to say that the problem of controls has finally been mastered. One may say, however, that the control problems, instead of being an art as in the past, now have become a science, so that it becomes possible to abandon the earlier "cut and try" methods and to proceed systematically by overcoming one difficulty after another.

The whole variety of modern controls, from the thermostat controlling the oil burners in homes to the more spectacular applications in aviation, power plants, industrial processes, railroads, naval architecture, etc., appears now as a unified applied science proceeding systematically along a normal path of gradual perfection. Created by man, it eliminates man from tedious jobs, like that of the boy pulling the rope of the valve of a steam engine, and gives the human race better opportunities to concentrate on more constructive activities.

Gravity Die Casting in Non-ferrous Alloys. (*Machinery*, Vol. 64, No. 1646.) Phosphor bronze, manganese bronze and gunmetal are not generally suitable for die casting, as they lack fluidity; but it depends on the intricacy of the desired casting, and gunmetal can sometimes be used. Naval brass and aluminium bronze are both excellent in their own sphere, but the wear on the dies is greater with the latter. A graphite dressing for the dies not only protects them but also increases the fluidity of brass, naval brass and aluminium bronze.

As a general rule, the weight of the runner plus any risers is one and a half times to twice that of the metal in the casting, according to the type of casting and where it can be fed, but castings weighing, say, 3 or 4 grm. may require as much as eight times their own weight to bring corners or edges up sharply. Plates are inserted in the die, or vent plugs or fine lines cut to allow the air to escape so that the metal may entirely fill the die. The heavy feed assists in the weight behind the casting, and the runner is finally cut off and returned for remelting. The designer can usually foresee where contraction will occur and place a riser there so that the metal can feed back.

The maximum weight for die castings is generally between 20 and 30 lb., but the greater difficulty that is experienced in working the larger dies must be borne in mind as well as temperature control. Another factor to be considered is whether the number of castings justifies the cost of the big die. In wartime, when large quantities are required, larger castings, which might otherwise have been produced as sand castings, are being made as die castings, but in these cases the saving is achieved in constancy of dimensions.

The risk of rejects in the larger castings is relatively a more serious matter, while the larger dies require special arrangements for heating and hydraulic gear for their operation, so that the production cost is higher pro rata than for the smaller castings.

The die is preheated before casting, and dipping in the dressing solution before each cast reduces its temperature to the working condition. As a result, the surface of the die shows a number of cracks in course of time, and the die eventually fails by cracking and recomposition of the surface. If allowed to continue in use, the die might get to the stage where an undercut was created by metal flowing into the cracks, and difficulty might be experienced in releasing the casting from the die. The core pieces have to be replaced more often, as they are usually of small dimensions, and consequently burn and crack more easily.

P.

NUTRITIONAL ENGINEERING, I: AGRICULTURE AND HUMAN NUTRITION.

BY

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Every time a farmer grows a really good plant or animal, he is demonstrating a fact and principle that people have been slow in applying to themselves. This is the fact that full health is more than merely freedom from disease; rather, it is a positive quality of life that can be built to higher levels. To generalize this fact, and give it a formal scientific aspect, we may call it the principle of the improvability of the norm.

For a farmer to find real satisfaction in a plant or animal he has grown, it must be better than merely a normal, it must be a superior, specimen of its kind.

Now the farmer builds these superior individuals and so improves the norm of his crop or herd, first by breeding, and second by feeding and otherwise providing a favorable environment.

Gove Hambidge has pointed out that the norm of our American population would be improved if all children were reared with as much regard to their attainments in positive health as are the animals in a good farmyard.

Our present-day view of nutrition does not, in any way whatever, encroach upon the field of the geneticist; we do *not* believe that we have changed, nor do we aspire to change, the germ plasm by improving an already normal diet. Heredity and environment determine the life history; and in this sense, the word environment, by definition, covers all influences except the genetic. But, in practice, most of us tend to think of environment as that which surrounds the body, and so most of us are late in waking up to the importance of differences in that part of our environment which each of us carries within his own skin—the *internal environment* of the body.

The reason we have hitherto neglected to take due account of the differences in our internal environments is in one sense quite simple. We did not believe in the existence of such differences. We thought we had learned from two great teachers, Liebig in chemistry and Claude Bernard in physiology, that the internal environment is a constant for the normal members of a given species, at least at any given stage in the life history. Liebig taught farmers to fertilize their fields, with phosphate for example, but with the expectation of getting a bigger

crop rather than a crop richer in phosphorus. For, aside from such non-essentials as the amounts of stored starch or fat, the chemical composition (at a given stage of maturity) was believed to be specific for the species. And what Liebig had arrived at through agricultural chemistry Claude Bernard formulated in the physiological phrase that it is because of the *fixité* of the internal environment that organisms are able to cope with new or changeable external environments. These teachings have been of great service to agriculture on the one hand and to physiology and ecology on the other; but they are only first approximations.

With the universally accepted principles of physical chemistry, and with the experimental facts of the newer knowledge of nutrition, we now have the means of deeper insights and of more far-reaching scientific concepts which both "render more intelligible the world in which we live," and are turning out to have an unexpectedly great practical importance for the development of human health and efficiency, through better use of food.

The fact that this new knowledge of nutrition offers unexpectedly great potentiality for the improvement of human efficiency at a time when our country so much needs our best efforts, and also offers guidance in the practical food problems which are now so acute in our national and international affairs, naturally arouses enthusiasm in some people and skepticism in others.

In this situation, agricultural thinking can render a great service. Every thoughtful agriculturist knows—whether he uses these words or not—that a satisfactory plant or animal must have something of that *higher health* that is more than merely absence of disease. And he knows that, important as is the genetic heritage, much also depends upon the nutritional environment. The skeptical economist who as yet is refusing to believe that anything more than slight improvement of human efficiency and welfare can result from a moderate redirection of our present national resources for food production as advised in the government's published goals for 1944, can reassure himself and move forward out of his skepticism by learning from his farmer friends that what is now "claimed" for human nutrition is just the sane counterpart of what scientific agriculture has already demonstrated in the flocks and herds of the progressive farmers of the nation, and that both for human beings and for crops and farm animals, there is good prospect that further research will point the way to still higher achievements.

Meanwhile, the trend of the food production goals has important significances both industrial and nutritional which we plan to take up in subsequent installments of this paper.

March 18, 1944.

(This is the first of a series of articles by Dr. Sherman. Others will appear in future issues of the JOURNAL OF THE FRANKLIN INSTITUTE.)

ON THE ACTION OF ELECTROSTATIC ALTERNATORS.

BY

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ABSTRACT.

A detailed analysis, based on a consideration of charges and potentials, is made of the action of two simple electrostatic alternators; a four-symmetric, four carrier, machine, and a trisymmetric, six carrier, machone. Each of the machines is the prototype of a whole family of polysymmetric electrostatic alternators, and the method of analysis is extended to the generalized machine of each type. A basis for a qualitative theory of electrostatic alternators is evolved.

The theory of electrostatic alternators previously developed[1, 2] was based almost entirely on a consideration of the potentials involved; and while such a course is sufficient to predict the behavior of machines of this type, it is unsatisfactory in that it does not give an insight into their action. The present work was undertaken to supplement the previous theory in this respect, as well as to develop a qualitative theory of these machines.

For this purpose a detailed analysis is made of the action of two simple electrostatic alternators: namely, a four-symmetric, four carrier, electrostatic alternator (Fig. 1), and a trisymmetric, six carrier, electrostatic alternator (Fig. 2), both of which have been previously treated by the present author.[3, 4] These two are chosen in preference to others, for the reasons that they are probably the two simplest species of electrostatic alternator, and that each is the prototype of a whole family of such machines, the action of which is thus clarified.

1. ACTION OF THE FOUR-SYMMETRIC MACHINE.

The first machine to be studied is shown diagrammatically in Fig. 1. It consists of four fixed inductors and four revolving carriers, and has four brushes and brush arms so arranged that each carrier, as it leaves the position directly in front of an inductor, is connected momentarily to the next inductor in the direction of rotation. The machine is assumed to possess fourfold symmetry and all brushes are assumed to break simultaneously. Experimentally it is observed that such a machine not only builds up high voltages but also reverses its polarity

[1] A. W. Simon, *Phys. Rev.*, **26**, p. 111 (1925).
[2] A. W. Simon, *Phys. Rev.*, **27**, p. 747 (1926).
[3] A. W. Simon, *Phys. Rev.*, **25**, p. 368 (1925).
[4] A. W. Simon, *Phys. Rev.*, **28**, p. 142 (1926).

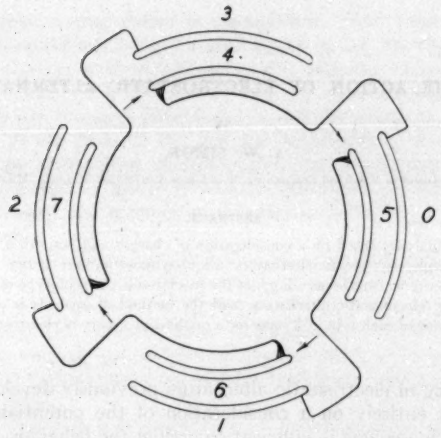

FIG. 1. Four symmetric, four carrier, electrostatic alternator.

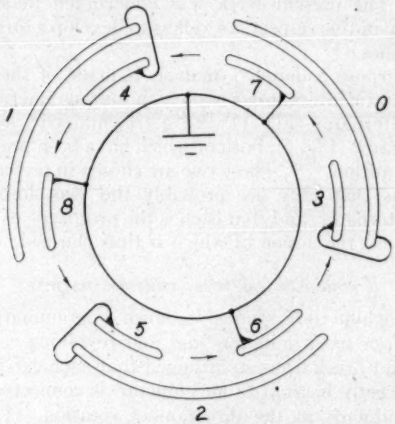

FIG. 2. Trisymmetric, six carrier, electrostatic alternator.

with the greatest regularity—a reversal occurring approximately every revolution.

Provided that the potentials of successive inductors are initially 90° out of phase, and provided also that the maximum positive potential V resides initially on the inductor indexed 0 (or the inductor on which the

maximum positive potential initially resides is indexed 0), the rigorous quantitative theory gives for the potential $V_s(n)$ of the inductor indexed s, after n quarter turns, in the position where the carriers just break contact with the brushes:

$$V_s(n) = V\rho^n \cos [n\theta - s(\pi/2)], \tag{1}$$

where ρ and θ are functions only of the electrostatic coefficients of the conductors in the position noted.[5]

If we neglect all coefficients of induction except those arising from the interaction of each inductor s with the carrier t immediately in front of it, and, furthermore, assume that these satisfy the equation:

$$+ a_{ss} = a_{tt} = - a_{st} = c, \tag{2}$$

the quantities ρ and θ reduce to:[6]

$$\rho = \sqrt{2}, \tag{3}$$

$$\theta = \pi/4, \tag{4}$$

and the equation for the potentials of the inductors reduces to:

$$V_s(n) = (\sqrt{2})^n V \cos [n(\pi/4) - s(\pi/2)]. \tag{5}$$

From Eq. (5) we have further:

$$V_{s+1}(n + 2) = 2V_s(n), \tag{6}$$

from which it is readily seen that we need to follow the action of the machine for only one-half revolution ($n = 0, 1, 2$), since then the whole process is repeated, except that all the potentials have been doubled and advanced one quarter turn (i.e. to the next inductor) in the direction of rotation.

By substituting in the fundamental equation:

$$Q_j(n) = \sum a_{ij} V_i(n), \tag{7}$$

we find that the charge $Q_s(n)$ of the inductor indexed s, after n quarter turns, is given by:

$$Q_s(n) = Q(\sqrt{2})^{n+1} \cos [(n + 1)(\pi/4) - s(\pi/2)], \tag{8}$$

where Q is the initial charge of the inductor indexed 0, and is related to the initial potential V of the same inductor by the equation:

$$Q = cV. \tag{9}$$

Furthermore, from Eqs. (5) and (7), it follows that between the charges of inductors and carriers there exists the simple relation:

$$Q_t(n) = - Q_s(n), \tag{10}$$

[5] A. W. Simon, *loc. cit.*[3]

[6] A. W. Simon, *loc. cit.*[3]

while from Eqs. (5) and (8) it is readily seen that the potentials and charges of the inductors satisfy also the relations:

$$V_0(n) = -V_2(n), \quad (11) \qquad V_1(n) = -V_3(n), \quad (12)$$

$$Q_0(n) = -Q_2(n), \quad (13) \qquad Q_1(n) = -Q_3(n) \quad (14)$$

so that in any one position we need calculate only the potentials and charges of two successive inductors, in particular those indexed 0 and 1.

Setting, therefore, n equal to 0, 1, and 2; and s equal to 0 and 1, in Eqs. (5) and (8); we obtain for the corresponding potentials and charges the values given in Table I.

Let us consider now the potentials and charges of the conductors of the system in the several positions in order.

In the initial position the inductor 0 and the carrier 4 connected to it are at a potential $+V$, the inductor 2 and the carrier 6 connected to it are at a potential $-V$, while the intermediate inductors 1, 3, together with the carriers 5, 7, connected to them, are at zero, i.e.

TABLE I.

n	$V_0(n)$	$V_1(n)$	$Q_0(n)$	$Q_1(n)$
0	$+V$	0	$+Q$	$+Q$
1	$+V$	$+V$	0	$+2Q$
2	0	$+2V$	$-2Q$	$+2Q$

ground, potential. Under these conditions the conductors at potentials $+V$ and $-V$ induce oppositely signed charges on the conductors immediately in front of them; or we might describe the action by saying that the positively charged inductor 0 and the negatively charged carrier 6 produce an electrical separation of charge in the symmetrically placed system comprising the carrier 5 and the inductor 1, the brush arm performing the function of a "neutralizing rod"; and that the inductor 2 and carrier 4 behave similarly with respect to the symmetrically placed system comprising the carrier 7 and inductor 3, except that the signs of the charges are everywhere reversed. In this position then the carriers 4 and 6 perform the function of *inductors*.

The respective potentials and charges in the initial position are shown conveniently by means of the developed diagram of Fig. 3a. The dotted grounds indicate that the corresponding systems are at ground potential although not actually connected to earth.

As the carrier disc now rotates the carriers break contact with the brushes, and, carrying with them the charges they possessed in the initial position, advance one quarter turn until they again make contact with the brushes.

In the second position (Fig. 3b), the carrier 5 and the inductor 2 give up their charges to the inductor 1 and the carrier 6, respectively; while the carrier 7 and the inductor 0 give up their charges to the inductor 3 and the carrier 4, respectively. We might say the mutual attraction of the oppositely signed charges on the carrier 5 and the inductor 2 cause them to flow onto the conductors 1 and 6; and the same holds for the charges on the carrier 7 and the inductor 0, and the conductors 3 and 4, respectively. The conductors 0, 2, 5, 7 are thus left without charge.

In the third position (Fig. 3c), the carrier 5 and the inductor 1 are raised to a potential $+ 2V$; the carrier 7 and the inductor 3 are lowered

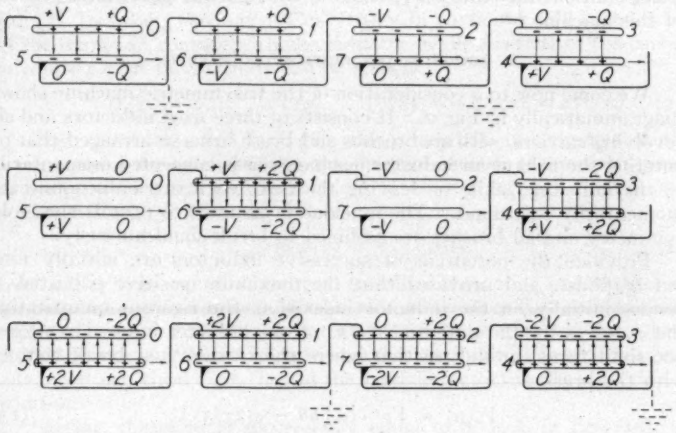

FIG. 3. Developed diagram of the action of the four symmetric machine.

to a potential $- 2V$; while the symmetrically placed systems comprising the conductors 6, 2 and 4, 0 assume the potential 0. The system as a whole is now in the original state, except that all the potentials have been doubled and advanced one quarter turn in the direction of rotation, with the maximum positive potential now residing on the inductor 1.

The process described then repeats with the result that at the end of *one* revolution all the charges and potentials have been quadrupled, and the maximum positive potential advanced *one half* turn in the direction of rotation, with the maximum positive potential now residing on the inductor 2, and so forth.

At the end of *two* revolutions then the maximum positive potential will again reside on the inductor 0, that is to say, a complete period

corresponds to *two* revolutions, but in the meantime the potentials and the charges have been increased sixteenfold. This explains the self-exciting property of the machine and the rapidity with which it builds up.

It is seen that the action of the machine can be described also by asserting that a potential wave of *continually* increasing amplitude travels around the machine in the direction of rotation.

Actually in practice the assumptions of Eq. (2) can be fulfilled only approximately with the result that θ is actually less than $\pi/4$, and ρ is less than $\sqrt{2}$. Hence the potential wave does not travel around in a period which is commensurate with the period of rotation. For the exact relations the reader is referred to the rigorous quantitative theory of this machine.[7,8]

II. ACTION OF THE TRISYMMETRIC MACHINE.

We come now to a consideration of the trisymmetric machine shown diagrammatically in Fig. 2. It consists of three fixed inductors and six revolving carriers, with six brushes and brush arms so arranged that on entering the field of an inductor, each carrier is connected momentarily to the inductor; while on leaving the field, each carrier is connected momentarily to ground. The machine is assumed to possess threefold symmetry and all brushes are assumed to break simultaneously.

Provided the potentials of successive inductors are initially 120° out of phase, and provided that the maximum positive potential V resides initially on the inductor indexed 0, the rigorous quantitative theory gives for the potential $V_s(n)$ of the inductor indexed s after n one-sixth turns, in the position where the carriers just break contact with the brushes:

$$V_s(n) = V\rho^n \cos\left[n\theta - s(2\pi/3)\right], \tag{15}$$

where ρ and θ are functions only of the electrostatic coefficients of the conductors of the machine in the position noted.[9,10]

If we neglect all coefficients of induction except those due to the interaction of the inductor s with the two carriers r and t immediately in front of it, and set:

$$a_{ss} = 2a_{rr} = 2a_{tt} = -2a_{sr} = -2a_{st} = 2c, \tag{16}$$

the quantities ρ and θ reduce to:[11]

$$\rho = \sqrt{3}, \tag{17}$$

$$\theta = -\pi/6, \tag{18}$$

[7] A. W. Simon, *Phys. Rev.*, **25**, p. 368 (1925).
[8] A. W. Simon, JOUR. FRANK. INST. (1944).
[9] A. W. Simon, *Phys. Rev.*, **28**, p. 142 (1926).
[10] A. W. Simon, JOUR. FRANK. INST., **237**, p. 177 (1944).
[11] A. W. Simon, *loc. cit.*[10]

and the equation for the potentials of the inductors becomes:

$$V_s(n) = V(\sqrt{3})^n \cos[n(\pi/6) + s(2\pi/3)]. \quad (19)$$

Physically the assumptions made in Eqs. (16) would require that the inductors completely surround the carriers, that the carriers are screened completely from each other by the inductors, and that the inductors are relatively far removed from each other and from ground.

Under these conditions, obviously, on contacting the inductor brush the carrier must give up all its charge to the inductor; while on contacting the grounding brush, a charge equal and opposite to that of the inductor is induced on the carrier.

Quantitatively this can be proved by means of the fundamental Eq. (7), by taking account of Eqs. (16). In particular, if r is the index of the carrier in contact with the inductor, while t is that of the carrier in contact with the earth, it can be shown:

$$Q_r(n) = 0, \quad (20) \qquad Q_t(n) = -Q_s(n) = cV_s(n). \quad (21)$$

Eqs. (19), (20), and (21) give the potentials and charges of the conductors of the machine after any integral number of one-sixth turns, in the position where the carriers just break contact with the brushes.

From Eq. (19) it readily follows:

$$V_{s+1}(n+2) = -3V_s(n), \quad (22)$$

from which it is seen that we need to follow the action of the machine for only one third of a revolution ($n = 0, 1, 2$), since the process is then repeated except that all the potentials (and the charges) have been tripled in value, reversed in sign, and the maximum potential has been advanced one third turn (i.e. to the next inductor) in the direction of rotation.

Setting, therefore, n successively equal to 0, 1, 2, in Eq. (19), we obtain for the corresponding potentials the values given in Table II.

TABLE II.

n	$V_0(n)$	$V_1(n)$	$V_2(n)$
0	$+V$	$-V/2$	$-V/2$
1	$+3V/2$	$-3V/2$	0
2	$+3V/2$	$-3V$	$+3V/2$

It is not necessary to set up a table for the charges, since under the assumed conditions, these will be proportional simply to the corresponding potentials.

Consider now the potentials and charges of the conductors of the machine in the various positions in order.

In the initial position (Fig. 4a) the inductor 0 is at a potential $+ V$, while the inductors 1 and 2 are at potentials $- V/2$. Under these conditions the inductor 0 induces a charge $- Q$ on the carrier 7, while the inductors 1, 2 induce charges of $+ Q/2$ on the carriers 8, 6, respectively. The process might also be described by saying the positively charged inductor 0 and the negatively charged inductors 1, 2 produce an electrical separation in the system comprising the carriers 6, 7, 8; a charge $- Q$ appearing on the carrier 7, and charges $+ Q/2$ on each of the carriers 6, 8; the brush arms acting as "neutralizing rods."

One sixth turn later (Fig. 4b) these carriers (now in positions 3, 4, 5 respectively) give up their charges to the respective inductors, with

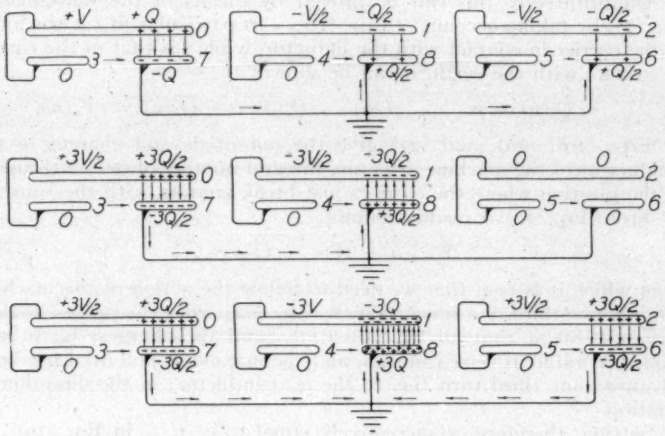

FIG. 4. Developed diagram of the action of the trisymmetric machine.

the result that the inductors 0, 1, 2, now possess charges $3Q/2$, $- 3Q/2$, and 0, respectively, thus raising them to potentials $+ 3V/2$, $- 3V/2$, and 0, respectively. The inductors 0, 1, 2, in turn now induce charges $- 3Q/2$, $+ 3Q/2$, and 0 on the carriers in positions 7, 8, 6, respectively, and these charges are transferred to the inductors one-sixth turn later, with the results (Fig. 4c) that the inductors 1, 2, 0 are raised to potentials $- 3V$, $+ 3V/2$, $+ 3V/2$, respectively. However, this distribution is the same as the original one except that all the potentials have been tripled, reversed in sign, and advanced one third turn in the direction of rotation. The process then repeats with the result that at the end of one revolution the maximum potential resides on the inductor indexed 0 but is reversed in sign, while after two revolutions the system is returned to its original state except that all the potentials have been

increased in the ratio of 3^6. A complete period therefore corresponds to two revolutions.

The action can be described also by saying that a potential wave of continually increasing amplitude travels around the machine in the direction of rotation.

III. THE GENERALIZED MACHINE OF FIG. 1.

The machine of Fig. 1 is the four-symmetric member of a whole family of polysymmetric electrostatic alternators, in which the number m of symmetries can be both even and odd.[12] The action of these machines can be analyzed by assuming that in the initial position the potentials of successive inductors differ in phase by an angle $2\pi/m$. However, both in the case of the four symmetric and polysymmetric machine, other simple modes of operation are possible.[13] These simple modes are found by setting the initial difference of phase of successive

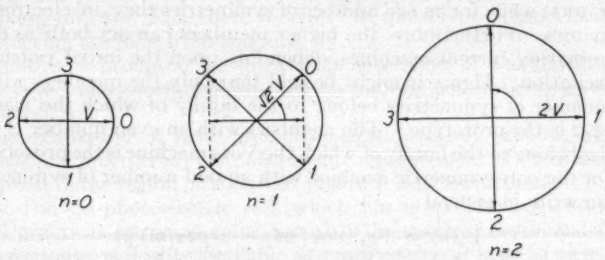

FIG. 5. Graphic method of finding the potentials of the inductors in successive positions.

inductors equal to $p(2\pi/m)$, where $p = 0, 1, 2$, etc. For example, in the case of the four symmetric machine of Fig. 2, we can set p equal also to 0 and 2, corresponding to the case where the original potentials are all equal, in which case no change takes place; or where they are alternately equal but opposite, in which case the inductors are merely discharged.

For the polysymmetric machine, we can write in general:

$$V_s(n) = V\rho_p^n \cos\left[n\theta_p - s(2\pi p/m)\right], \tag{23}$$

where m is the number of symmetries of the machine and p the index of the simple mode of operation. Furthermore under the assumptions of Eq. (2), ρ_p and θ_p reduce to:

$$\rho_p = 2\cos\vartheta_p/2, \tag{24}$$

$$\theta_p = \vartheta_p/2 = p\pi/m, \tag{25}$$

where

$$\vartheta_p = p(2\pi/m). \tag{26}$$

[12] A. W. Simon, *Phys. Rev.*, **27**, p. 747 (1926).

[13] A. W. Simon, *loc. cit.*[12]

The initial potentials ($n = 0$) to be assigned to the inductors of the machine for the mode of operation indexed p, are given graphically by the projections on the polar axis of p vectors each of length V plotted at equal angles of ∂_p apart. Also the potentials corresponding to subsequent positions ($n = 1, 2, 3$, etc.) are given graphically by the projections of p vectors each of length $\rho_p{}^n V$ drawn at angles ∂_p apart and rotated through an angle $n\theta_p$. The corresponding diagrams for the machine of Fig. 1, for which $m = 4$, for the mode of action and positions discussed in detail, namely $p = 1$ and $n = 0, 1, 2$, are shown in Fig. 5.

IV. THE GENERALIZED MACHINE OF FIG. 2.

The machine of Fig. 2 is the trisymmetric member of a whole family of polysymmetric electrostatic *generators*, in which the number of symmetries also can be both even and odd.[14] However, for an *even* number of symmetries the corresponding members are inherently direct current generators; while for an *odd* number of symmetries they are electrostatic alternators. Furthermore, the higher members can act both as direct or alternating current machines, depending upon the initial potentials, i.e. excitation. Hence it might be said that only the members with an odd number of symmetries belong to the family of which the machine of Fig. 2 is the prototype. The members with an even number of symmetries belong to the family of which the Voss machine is the prototype.[15]

For the polysymmetric machine with an odd number of symmetries, we can write in general:

$$V_s(n) = V\rho_p{}^n \cos\left[n\theta_p - s(p2\pi/m)\right], \qquad (27)$$

where again m represents the number of symmetries and p the index of the mode of operation. Under the assumptions of Eq. (16) ρ_p and θ_p reduce to:

$$\rho_p = 2 \sin \partial_p/2, \qquad (28) \qquad\qquad \theta_p = (\partial - \pi)/2, \qquad (29)$$

where

$$\partial_p = p(2\pi/m). \qquad (30)$$

The graphic method of finding the potentials can be employed in this case also.

In conclusion it might be pointed out that of the various simple modes of operation that corresponding to $p = 1$ might be termed the fundamental or principal mode of operation; that corresponding to $p = 2$, the first harmonic mode, etc.

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[14] A. W. Simon, *Rev. Sci. Inst.*, 1, p. 57 (1930).
[15] A. W. Simon, *Phil. Mag.*, 49, p. 257 (1925).

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

RADIOMETRIC METHOD OF TESTING ULTRAVIOLET SCREENING PROPERTIES OF SUNBURN PREVENTIVE CREAMS.

The number of salves, creams, and lotions available for protecting the skin from sunburn is legion. They are of three types: Those that contain substances highly opaque to ultraviolet rays of wave-lengths shorter than 3250A; those that contain substances that diffusely reflect these rays; and those containing substances that do both. Assuming that they meet the requirements of not holding dust and sand, freedom from rancidity, not interfering with transpiration, and not irritating to or soaking into the skin, there remains the question of their efficiency in protecting the skin from sunburn.

Sunburn is produced by ultraviolet solar rays of wave-lengths of about 3250A and shorter, the maximum burning action being at wave-length 2967A.

The evaluation of light protective substances, in general, by the physiological (erythema) test; also by the measurement of their spectral absorption in the region of 2900A to 3250A, is slow and tedious. Fortunately, the Cd-photoelectric cell, which has a spectral response that for all practical purposes coincides with the spectral erythemal (sunburn) response, is readily available as a radiometer, at least as an instrument for sorting out the relatively good from the optically unsatisfactory sunburn preventive creams. W. W. Coblentz, chief of the Bureau's radiometry section finds that the particular Cd-photoelectric cell that meets the requirements as an ultraviolet radiometer, suitable for this purpose, is constructed in the form of an opaque, pear-shaped bulb (GE type FJ–135). The whole interior of this bulb is photosensitive and hence integrates the ultraviolet radiation of wave-lengths 3250A and shorter that enters through the window, which is covered with a diffusing screen as shown in Fig. 2 of *Bul. Amer. Meteorol. Soc.*, **18** (November 1937); also Fig. 1 of *J. Research*, NBS **20**, 185 (February 1938), RP1075, and Fig. 6 of **22**, 573 (May 1939), RP1207.

The opacity of the sunburn preventive cream (pressed between two thin plates of quartz, Corning Corex-D No. 970, or light silica glass No. 791) is determined by holding it over the diffusing window of the Cd-photocell, which as already mentioned integrates the diffusely incident radiation.

The auxiliary measuring instrument, which must be capable of

* Communicated by the Director.

measuring transmissions accurately to 0.1 per cent., is a microammeter and amplifier (*J. Research*, NBS **12**, 231 (February 1934), RP647); a high-resistance, high-sensitivity galvanometer, or other suitable meter. The source is a hot quartz mercury arc, or carbon arc lamp covered with a Corex-D window.

SELF IGNITION OF WOOLEN MATERIALS.

Many combustibles become heated and take fire spontaneously under conditions that are sometimes met with in shipping or storage, if the surrounding temperatures are too far above normal. This problem has been studied extensively in relation to oils, fats, vegetable fibers, coal and many other materials. Little is known about the behavior of woolen materials because their reaction differs from that of most other combustibles. If the material is heated to a point where the fibers melt, ignition does not take place below temperatures of about 525° C. when the material gives off gases that are ignited.

At the Bureau, the behavior of woolen materials has been studied in the 1000 ml. ignition flask designed for self-ignition determinations. It is found that when the air supply is properly regulated, self heating and ignition occurs from an initial temperature of only 215° C. The material for this test was from khaki colored blankets containing less than 1 per cent. of cotton and some wool fat. No ignition took place below 525° C. with samples of pure scoured wool.

PROPERTIES OF HOUSEHOLD BLANKETS.

An investigation of blankets, recently completed by H. F. Schiefer, H. T. Stevens, P. B. Mack, and P. M. Boyland of the Bureau's textile section, was undertaken to provide adequate test methods and to supply basic data as a guide for a performance specification. The results are given in RP1589 in the June number of the *Journal of Research*.

Blankets are an essential article in every place of abode, and in war they form a vital part of the protective clothing of the soldier, sailor, and marine on battle fronts and in training camps. They furnish shelter to the wounded and to those forced to take to life boats and life rafts at sea. In time of peace, blankets are a first consideration for camping and other outdoor recreation and sport. In a major emergency they provide temporary shelter to the unfortunate victims whose lives may depend upon the warmth afforded by blankets.

Although blankets are so important in war and in peace, adequate methods for testing them and essential information about their performance characteristics have not been available. Changes in the softness, resiliency, flexibility, fluffiness, and warmth of blankets often

result from excessive mechanical action during washing and too high and uncontrolled temperature and alkalinity of the wash waters.

In the investigation at the Bureau, the fiber composition, weight, thickness, compressibility, compressional resilience, thermal transmission, air permeability, breaking strength, and shrinkage of 156 different blankets were measured. The effects of laundering; of laundering and renapping; of laundering, renapping, and abrasion; of dry cleaning and renapping; and of dry cleaning, renapping, and abrasion on these properties of a large number of blankets are brought out in the report. A linear relationship was found between the compressional resilience and the wool content of cotton-wool blankets. Thermal transmission was found to be independent of the kind of fiber, but its reciprocal was found to be related linearly to the thickness. The thermal transmission, computed by means of the equation $1/T = 3.0t_{0.1} + 0.63$, where T is the thermal transmission in B.t.u./(° F. × hr. × ft.²) and $t_{0.1}$ is the thickness in inches at a pressure of 0.10 lb./in.², was found to agree with the measured valued within ± 10 per cent. 95 times out of 100. Empirical relationships were also found among thermal transmission, thickness at 1.0 lb./in.², and compressibility; and among thickness at 0.10 lb./in.², compressibility, and weight. The relation between breaking strength and weight, and that between breaking strength and compressibility, are discussed. Minimum requirements are suggested for the properties of blankets for use in a performance specification.

PURIFICATION OF SUBSTANCES BY SLOW FRACTIONAL FREEZING.

Residents of Maine are reported sometimes to have employed their native ingenuity to make a potent liquor merely by allowing a barrel of hard cider to stand out of doors in freezing weather until a substantial part of the water has frozen as a thick coating of ice on the inside of the barrel. Thereafter the remaining liquid, now greatly concentrated, is drawn off.

The same physical principle is involved in the technics for purifying chemical substances by slow fractional freezing that are described by Frank W. Schwab and Edward Wichers in the June number of the *Journal of Research* (RP1588). Two variations of this method were applied to the purification of benzoic acid (a substance commonly used as a chemical standard) and were found much more effective than previous trials of crystallization from solvents. In the first of these technics, a cylindrical vessel containing the fused substance is slowly lowered, by means of a floating table, through a heating coil. Freezing begins at the bottom and progresses upward as the tube emerges slowly from the heated zone. The impurities in the substance tend to remain in the liquid, which is constantly stirred, and thus are concentrated in

the portion which freezes last. After the whole mass is frozen, the upper end is cut off and discarded.

In the second technic, which is applicable to larger quantities of material and which also provides a greater area of solid surface in proportion to the quantity of material to be frozen, a spherical flask is filled with the molten substance and is then buried in highly efficient thermal insulation. Freezing begins on the wall of the flask and is allowed to progress slowly inward until the desired fraction has solidified. During this period the liquid is constantly stirred to prevent accumulation of impurities at the boundary between the solid and the liquid. The portion of liquid which is to be discarded is drawn off with a siphon.

The second technic was also used for preparing highly purified acetanilide, another substance issued by the Bureau as a chemical standard. This substance, like benzoic acid, freezes well above ordinary temperatures, so that the flask needed only to be well insulated to control the rate of freezing. The second technic can also be applied to substances freezing below room temperatures by refrigerating the outside of the container.

LAMINAR FLOW AT THE INTERFACE OF TWO LIQUIDS.

Liquids often move in layers having different densities, ocean and atmospheric currents being well-known cases of stratified flow. The mixing that generally accompanies such motion is of great geophysical significance, yet knowledge is lacking of exactly how the mixing takes place, or of the forces that tend to prevent it.

Two economically important manifestations or occurrences of stratified flow are found in water. One of these is the motion of muddy water through large reservoirs. Under certain circumstances the muddy water will traverse the whole length of the reservoir without losing its identity. On the other hand, if conditions are favorable, mixing of the muddy with the clear water is produced, and eventual settling of solid particles to the bottom of the reservoir occurs, which tends to fill up the reservoir with silt. For the proper operation and the efficient maintenance of reservoirs, it is highly desirable that the laws of passage of muddy water through fresh water be known.

The other phenomenon is the motion of salty water from the sea into the mouths of large rivers and to points farther upstream. The presence of salty water, especially if mixing is not prevented, becomes a serious problem when the water is used for domestic purposes and irrigation. In such cases it is also desirable that the law of mixing of fresh and salty water be known.

The usual method of obtaining the desired engineering information is to reproduce the condition causing the motion on a small scale in the laboratory. This procedure possesses the advantage of permitting

these conditions to be varied at will. However, when the problem arises of passing from the laboratory tests to the actual full scale behavior of the phenomena, the problem of transference equations comes to the fore. Is the method of transference legitimate? This question ordinarily does not arise where the phenomenon is definitely known to depend on a small number of physical quantities. If, on the other hand, the phenomena are complex, and this is obviously the case for the phenomena of mixing, caution must be exercised. In the main, this is because of the possibility that in the laboratory experiments some crucial quantities may have been ignored, or if recognized, their measurement may have been found impracticable. In the study of the phenomena of mixing in stratified flow, such crucial quantities may well be the magnitude and the origin of the random disturbances. These are difficult to deal with.

In these uncertain cases, a partial analysis of the phenomena must be resorted to; that is, complex phenomena are broken down into component problems and each is studied in its own environment. Among the phenomena of mixing in stratified flow, a partial problem which is readily recognized is the stability of the interface between the liquids of unequal density. The statement of the problem would be: Under what conditions do waves generated at the interface of two liquids fail to be amplified exponentially? This is a mathematical problem and is amenable to analysis, provided the configuration of the motion on the two sides of the interface is known. Information on this point seems to be lacking, and in the *Journal of Research* for June (RP1591), Garbis H. Keulegan presents a mathematical derivation of the state of flow on the two sides of the interface.

THE QUATERNARY SYSTEM SODA-LIME-SILICA-WATER.

The soda and potash in portland cements occasionally produce undesirable effects on the properties of cement products. Thus, concrete made of high-alkali cements and aggregate containing reactive siliceous materials, as opal, are known to expand excessively. The role of the alkalies in the various processes of hydration is not fully understood. Information on how they alter the composition of the different reaction products should prove useful in explaining the hydration of cements, both in the presence and absence of "reactive" aggregates. An investigation of the quaternary system soda-lime-silica-water at 25° C. was accordingly carried out by George L. Kalousek of the Bureau's lime and gypsum section, to provide a portion of the desired data.

As reported in the June *Journal of Research* (RP1590), the only solid phases found were calcium hydroxide and a soda-lime-silicate gel of variable composition. In the presence of excess calcium hydroxide, the composition of the gel varied between about $2CaO:1SiO_2:XH_2O$ (with

no soda present in solution) and $1Na_2O:4CaO:4SiO_2:XH_2O$ (soda concentrations of 20 to 150 g. of Na_2O/liter). In the absence of excess calcium hydroxide, the ratio of CaO to SiO_2 of the gels decreased with increasing amounts of SiO_2 in the contact solution.

The study indicated that the $CaO:SiO_2$ molar ratio of the lime silicate gels in hydrated cement may vary, the extent of variation depending on the alkali content of the cements. These gels will also contain a small amount of alkali. Low-lime alkali-silicate gels, comparable in composition to those found accumulated in voids in expanding concrete, cannot exist in the presence of calcium hydroxide. It may be that the presence of such gels in concrete is possible because, as postulated recently by Hansen, membranes are formed that separate the alkali silicates from the calcium hydroxide.

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COMMITTEE ON SCIENCE AND THE ARTS.

MINUTE ADOPTED BY THE COMMITTEE ON SCIENCE AND THE ARTS ON THE OCCASION OF THE DEATH OF MR. CHARLES STUART BALLANTINE.

The Committee on Science and the Arts records with deep regret the death of its very able and devoted member, Charles Stuart Ballantine, on May 7, 1944, at the Morristown Hospital, Morristown, New Jersey. A member of the Institute since 1926, Mr. Ballantine served on the Committee on Science and the Arts since 1935. Due to his health and the remote location of Boonton, New Jersey, which was his residence, the occasions when he was able to attend our meetings were rare. The Secretary has many times commented, however, on the high degree of ability, broad scientific knowledge and conscientiousness of Mr. Ballantine's service to this Committee. His services on the Franklin Medal Committee and many Sub-Committees have been invaluable.

Your Special Committee has reported more fully on the activities of Mr. Ballantine than is the normal custom for the reason that but few of our members had opportunity to know him by personal association.

Mr. Ballantine, son of Charles Mansfield and Mary Stuart Ballantine, was born September 22, 1897, in Germantown, Philadelphia. He attended the Philadelphia Public Schools, graduating from Northeast High School in 1916.

In the year 1908, at the age of ten, his interest in the infant art of wireless telegraphy was kindled by attending a Franklin Institute lecture to which he had been taken by his father who was then a member.

He recently commented on the significance of this lecture in shaping his future. For a number of years past his appreciation was evidenced by the fact that yearly he made available to his high school a block of tickets to the Christmas Lectures for Young Folk held at the Institute.

Mr. Ballantine was a tireless student, developing early in life an unusually keen mathematical and physical intuition. A tradition of the Ballantine neighbors was the light that always burned in Stuart's study.

During the years 1908 to 1916 wireless telegraphy, or as we now call it "Radio," passed through a developmental stage largely by the cut and try process. A fraternity of amateurs developed and their contributions constituted, to a considerable degree, the present framework of theory and technique of the art as it is known today.

Mr. Ballantine became one of the technical leaders of this amateur group, developing knowledge of the theories then known, and ability in equipment construction and operation.

His characteristic of devoting primary attention to fundamentals was indicated early in life in his close study of the then classical works of Fleming, Kelvin, Lodge and Heaviside. Failing to get results in requests to the Philadelphia Library he finally obtained the cooperation of the Friends Library in Germantown to provide him with the available writings of that time.

He reperformed the original experiments of Hertz, Marconi and Braun for his own education and inspiration of the faculties of the Philadelphia High Schools. His use of Braun's work with loops in order to locate sources of power line disturbance was pure pioneering and resulted in later valuable service during the first World War.

* Died in the Service.

While attending high school, he organized and guided a radio club, directing the design and construction of transmitting and receiving equipment and stimulating the club members by his ability to lucidly explain the various phases of this new art. Scholastically his records were outstanding in Mathematics and Physics.

It had been the ambition and expectation of Mr. Ballantine to enter Harvard University, however financial considerations at that time decreed otherwise. He entered the employ of the H. K. Mulford Company, bacteriologists, in 1916. In 1917 he was a night switchboard inspector for the Bell Telephone Company. In these years, he took courses in the Calculus at Drexel Institute Evening School.

During 1917 the United States Navy attempted to develop a radio direction finder suitable for use on shipboard. At that time direction finders required antenna structures of a size which made ship installation impracticable. It was known that German submarines reported nightly by radio to their home station at Nauen, Germany. If our destroyers could locate the position of these submarines by radio it was believed that their menace could be reduced. The most competent services of Navy, Signal Corps and the Bureau of Standards, together with very considerable expenditures of funds, had failed to produce a solution for this requirement.

The many activities of Mr. Ballantine as an amateur included studies of reception with loop antenna. This became known to the Navy and they appointed him Expert Radio Aide, setting up a suitable laboratory for the direction finder program at the Philadelphia Navy Yard. He gradually acquired a staff of associates and in a short time had accomplished the design, specifications and first production models of the initial coil type radio direction finder employed by the Navy. This equipment was within the dimensional limitations imposed by destroyer installation, gave both direction and sense observations, complete frequency coverage required, and was sufficiently simple in operation to be within the capabilities of radio ratings in the Navy. Nearly all of the destroyers of the last World War were subsequently equipped and the final summation credited this project with a large number of enemy submarines.

His second problem had to do with harbor protection. By means of suitably located radio direction finders at favorable points for triangulation, friendly vessels could be maneuvered into or out of harbors at all times and under practically all weather conditions. Delaware Bay was the scene of the first installation. Eventually all principle harbors on the coastline of the United States were equipped. Mr. Ballantine developed much new and valuable knowledge of the phenomena of coast line refraction and blocking filters to remove the biasing effects of nearby overhead lines on loop reception characteristics.

During this period he made several important contributions to the radio direction finder art, among which was a "compensator" to control "antenna effect" which resulted in a considerable increase in the sharpness and accuracy of observation, changing the entire aspect of this important art. This device is still in extensive use. For his work during the first World War in the field of radio direction finding Ballantine received a special award and citation from the Secretary of the Navy.

In 1919 Ballantine organized the Philadelphia Section of the Institute of Radio Engineers and acted as its first chairman.

Mr. Ballantine terminated his services to the Navy late in 1919. During his two years with the Navy he did much to train and inspire his associates since most of them have subsequently contributed greatly to the radio art.

It was now possible for Ballantine to consider an early ambition. He entered the Graduate School of Harvard University, qualifying by entrance examination, and taking courses under the direction of Dr. George W. Pierce. The winter of 1920–21 undoubtedly brought him much satisfaction. For the first time he had the stimulation of associates and advisors rather than the lonely experience of solitary study. The joy was short lived, however. The long vigils of younger years and the intensive efforts for the Navy brought on a collapse of his health and Ballantine went to White Haven, Pennsylvania, with every prospect of remaining there indefinitely.

This constituted a second frustration in his ambitions to gain a formal education. Undaunted, he occupied long hours and met financial problems by furnishing the Philadelphia

Public Ledger with a daily column on radio. It was considered a masterpiece of popular writing with lucid scientific character. Encouraged, Ballantine published "Radio Telephony for Amateurs," the first treatise of technical dignity available to the amateur fraternity. Eleven thousand copies through five editions were required to meet the demand which developed. Of this book, Dr. Alan Hazeltine, Professor of Electrical Engineering, Stevens Institute, states, "His book on 'Radio Telephony for Amateurs' was a classic; it included, I recall, a disclosure on filtering in receivers that anticipated a patent application which I had in preparation. His standard of invention was so high that I believe he did not apply for a patent on the idea."

By 1922 Mr. Ballantine appeared sufficiently recovered in health to enter an association with Dr. Lewis M. Hull, a classmate at Harvard, and early acquaintance from conferences with the Bureau of Standards during World War I. This association included Edward Weston, Dr. Leo H. Baekeland and Richard Seabury of Boonton, New Jersey. Their purpose was to build a research organization based on the considerable advancements which had resulted from war stimulation. This activity was known as the Radio Frequency Laboratories, Inc.

During 1922 Ballantine developed a new and fundamentally superior method of neutralizing radio frequency amplifiers, employing the Wheatstone Bridge principle. This circuit was the basis for the outstandingly successful broadcast receiver design of that time, being the first for which a single control was adequate. It subsequently became the crossed condenser method of neutralizing triode push-pull transmitter circuits now universally used. Other developments of his in this period were linear power detection and automatic volume control, both of which have remained standard practice.

Ballantine's health failed once again and he retired to White Haven, this time establishing his own laboratory where he could better maintain reasonable health.

During 1923 Ballantine developed the principles of negative feed-back to stabilize and reduce distortion in transmission circuits, modulators, amplifiers and detectors. This work was later to be further developed by Black in 1934.

Ballantine formulated the theory of vertical antenna, operated above its fundamental frequency. He showed that effective radiated energy could be doubled and better vertical distribution obtained by operation at approximately two and a half times fundamental frequency. The vertical radiator adopted by many broadcast transmitters resulted from this work which, incidentally, netted Ballantine no financial return. The Elliott Cresson Gold Medal was subsequently awarded to him in 1934 for this contribution.

Elected John Tyndall Fellow in Mathematical Physics by Harvard University, Ballantine undertook further study in the 1923–24 semester. By special action of the Corporation of Harvard University, he was invited to consider himself candidate for the degree of Doctor of Philosophy during this period despite lack of any previous college degrees; but again failing health overruled. He returned to White Haven, there to remain for the next three years.

The products of Ballantine's work in the period 1924 to 1927 included delayed automatic volume control circuits, together with many contributions to the broadcast industry both in transmitter and receiver design.

In 1927 Mr. Ballantine was able to discontinue permanent residence at White Haven. In this year he married Virginia Orbison of Huntington, Pennsylvania, and moved to Boonton, New Jersey. Here he assumed direction of research for the Radio Frequency Laboratories. The following year he disclosed an error in the accepted method for calibrating condenser type microphones and proposed the "free field" method of calibration now generally employed in acoustic measurements. This work brought him the Morris Liebmann Memorial Award in 1931 by the Institute of Radio Engineers.

During 1929 Ballantine became interested in vacuum tube theory and design. He is credited with substantial contributions resulting in reduced vacuum tube circuit noise. Working in collaboration with H. A. Snow he developed the remote cut-off or "variable-mu" principle of vacuum tube construction. This constitutes one of Mr. Ballantine's most valuable and basic contributions. It eliminates to a great extent cross-talk and modulation distortion in radio receivers. Many millions of this type vacuum tube have since been manufactured

and much of both peacetime and military radio equipment now in use is based on the operating characteristic of this tube type.

Perhaps by reason of his keen musical ability Ballantine continuously pioneered in high quality broadcasting. The present day excellence is appreciably to be attributed to his continued and patient efforts in the face of indifferent interest by broadcasters of that time. Working with the transmitter at Wayne, New Jersey, of the Columbia Broadcasting System, a demonstration was finally staged in 1933 before the Institute of Radio Engineers that did much to initiate competitive high fidelity development.

In 1930 Radio Frequency Laboratories was disbanded, patents disposed of, and Mr. Ballantine organized his own activity under Boonton Research Corporation, later Ballantine Laboratories, Inc. For the next several years he furnished consulting service in the broadcast field, always in the interest of improved fidelity. He developed the first device to provide a complete loud-speaker characteristic, accomplishing in a few moments the laborious point-by-point measurement requiring hours of work, yet not giving a continuous characteristic. The desirability of such a measuring device contributed much to fidelity improvement of loud-speakers.

During 1935 Ballantine served as President of the Institute of Radio Engineers.

About 1934 Ballantine initiated the first throat or larynx type microphone. This required a tremendous amount of fundamental study, both electrical and physiological. This microphone picks up voice sounds directly from the walls of the larynx as compared with the conventional type actuated by oral pressure waves. The acceptance of this device by the Service Air Forces was immediate since it freed pilots' hands, permitted oxygen mask use and excluded engine and propeller noises. Mr. Ballantine faced and met demands for this development which required extensive manufacture under extremely close tolerances. Seven patents were granted on this device, some basic in nature. Developed long before Pearl Harbor, these microphones are rendering useful service in World War II aircraft and tanks.

Other contributions which are factors in this present war consist of apparatus for supersonic underwater detection and an artificial ear for standardizing telephone head sets. These activities engaged Ballantine's energies until 1937. Since that time his attention was directed increasingly toward military problems.

A unique amplifier for use in bombers was developed by him having the very distinct advantage of requiring no high voltage supply dynamotor, saving weight and power drain. Ballantine developed and manufactured under laboratory control conditions a vacuum tube voltmeter of such high precision and frequency fidelity that it constitutes a measuring instrument on which standard performance of much radio equipment is now based. The demand for this instrument was increased a hundred fold by the requirements of war production and he was faced with the rigors of "big business" responsibilities.

In the past several years problems of many descriptions were brought to Mr. Ballantine, by the national research organizations with military problems, and by his associates of former years, now engaged in their own programs. Lastly, he undertook and made progress on a pure research assignment from the National Defense Research Council but the sands of his energies ran out. The first World War brought him heavy physical handicaps, the second the complete measure of his life.

Mr. Ballantine was:

Fellow, Institute of Radio Engineers
Acoustical Society of America
American Physical Society

Member, The Franklin Institute
Radio Club of America
American Institute of Electrical Engineers
American Society for Metals.

He published one book, contributed about fifty papers on scientific subjects and approximately thirty patents have been issued to him.

Of Mr. Ballantine, Major Edwin Armstrong expresses the opinion that he was the most versatile radio engineer of high ability of this age. Dr. Hazeltine makes the following comment: "He was intensely human as well as scientific. His courage in overcoming the handicaps of lack of financial resources and of continued ill health was outstanding. His record was one of the few that could properly be expressed in superlatives."

His friends will ever remember his idealism and rare ability to give council in their problems with the generosity and kindly understanding of the true gentleman. A worldwide scientific fraternity of his acquaintances marks his passing with the realization that but for his modesty and ill health he would have been of far greater recognized prominence.

BE IT RESOLVED, That this Minute be spread upon the records of the Committee on Science and the Arts and a copy of it sent to Mrs. Ballantine.

June 14, 1944

LIBRARY NOTES.

The Committee on Library desires to add to the collections any technical works that members would wish to contribute. Contributions will be gratefully acknowledged and placed in the library. Duplicates received will be transferred to other libraries as gifts of the donor.

Photostat prints of any material in the collections can be supplied on request. The average cost for a print 9 × 14 inches is thirty-five cents.

The library and the reading room are open on Mondays, Tuesdays, Wednesdays and Fridays from nine o'clock A.M. until five o'clock P.M., Thursdays from nine o'clock A.M. until ten o'clock P.M. Saturdays from nine until twelve o'clock noon.

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NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

Production and Properties of BRF Direct Cholera Vaccine.—ROBERT K. JENNINGS AND RICHARD W. LINTON. The description presented here is intended to serve primarily as a flow-sheet for those interested in producing BRF Direct Cholera Vaccine. Somewhat more elaborate methods have been employed in our work, for research purposes, and are described in detail elsewhere (Parts I and II, *Archives of Biochemistry*, **3**: 419 and 429, Feb. 1944, and Part III, *ibid*, in press). The actual production of the vaccine is a simple matter requiring a minimum of equipment and no especial technical skill. None of the conditions of growth specified is critical, and the entire process may be carried out by any laboratory technician.

The vaccine consists of an extremely heavy culture of *Vibrio cholerae* in a liquid medium which is physiologically innocuous and completely dialyzable. In addition to possessing certain advantages over previous types of cholera vaccine, the preparation represents an excellent source of vibrios for chemical and physico-chemical studies since the character of the substrate permits easy and complete removal of all non-specific materials.

OUTLINE OF THE METHOD OF PREPARATION.

A suitable strain of *Vibrio cholerae* is carried in stock cultures on agar slants. The actual inoculum of the BRF medium is prepared by inoculating a small flask of Salts-C-D (*Archives of Biochemistry*, **3**: 419, Feb. 1944) medium from these slants, and incubating without aeration until visible growth appears (12–24 hours). The entire culture is used as inoculum for the larger volume of BRF medium. The latter is then subjected to continuous aeration with air to which CO_2 (20 per cent. by volume) is added. Growth is complete in about 24 hours, at which time the culture is sterilized by the addition of phenylmercuric acetate, and distributed into suitable containers.

The entire culture, after suitable sterility tests, may be used directly as vaccine without further manipulation.

DETAILS OF THE METHOD.

Media. Two media are employed: one for inoculum, the other for the vaccine. The first is prepared from stock solutions as follows:

1. Salts. 0.5 per cent. $(NH_4)_2SO_4$, 0.075 per cent. K_2HPO_4, and 0.01 per cent. $MgSO_4$ in distilled water. The first two salts must be dissolved completely in about $\frac{3}{4}$th of the water, and the third in the re-

maining quarter. They may then be combined. The solution has been found to keep satisfactorily at room temperature without sterilization.

2. Casein digest (C-D). 100 gms. of commercial casein are suspended in 1 liter of water. The pH is adjusted to 8.0–8.5 with solid Na_2CO_3. Half a gram of trypsin (Difco) in 10 cc. of water is added and digestion allowed to proceed at 37° C. for 48 hours. It is advisable to add 2–3 cc. of chloroform to protect the mixture from bacterial contamination during this period. The flask is given an occasional shaking, and the pH is readjusted at intervals. After digestion, the pH is brought to 6.5–7.0, and any remaining solids are removed by filtration. The clear yellow filtrate is stored in the refrigerator over chloroform.

For use, the two stocks are mixed in the proportions of 1 liter of Salts to 15 cc. of C-D and the mixture autoclaved. Glucose in concentrated solution is autoclaved separately at 15 lbs. pressure. At the time of inoculation enough glucose solution to make about 0.1 per cent. final concentration is added, and the pH adjusted by the addition of 25 per cent. sodium hydroxide, *which does not need to be sterilized.* For liter cultures of BRF medium, 100 cc. cultures of Salts-C-D are used as inoculum. Six drops of the NaOH will bring the pH to a satisfactory range. For 13-liter batches (65,000 doses) of vaccine 1 liter of inoculum is used, and the NaOH is increased proportionately.

The BRF medium is prepared by sterilizing a mixture of water and C-D in the culture flask, adding the other ingredients at the time of inoculation. The C-D is used in the proportion of 15 cc. to 1 liter of water. $NaHCO_3$ is sterilized by autoclaving the salt wrapped in paper and placed in a Petri dish or beaker. Twelve grams are used for each liter of BRF medium. Enough glucose to make a 1 per cent. solution in the final medium is dissolved in a little water and autoclaved at 15 lbs. The glucose and bicarbonate are dissolved in the sterile dilute C-D solution just before use, and CO_2 is bubbled through for several minutes to overcome any excessive alkalinity which may have resulted from the heating of the bicarbonate.

DETAILS OF THE EQUIPMENT USED.

The Bubbler. The essential feature of the BRF culture method is the buffering action provided by the CO_2-bicarbonate interchange. Thorough and efficient aeration is therefore obligatory, and has been found to be most satisfactorily provided by the simple and inexpensive apparatus shown in Fig. 1. A piece of glass tubing is selected long enough to reach from about an inch above the stopper of the vessel to the middle of the medium in the flask. One end of this is flared and the other fire-polished. A circular piece is cut from unbleached muslin, linen from an old laboratory jacket, or any other coarse woven fabric. For use in a three-liter flask (1 liter of culture) a four-inch disk is about the right size. The bubbler illustrated is mounted in a 22-liter flask,

and was therefore made somewhat larger. Three concentric circles of white linen thread are stitched near the outer margin of the disc, using stitches about ¼ inch long and so placed that each pierces the cloth at a point about midway of a stitch in the adjacent circles. The ends of the thread should emerge at evenly spaced intervals around the circle. When these are drawn, the cloth forms a sack with the neck evenly puckered. The flared end of the glass tube is placed inside the sack and the thread drawn tight and tied. Heavy cord is whipped around

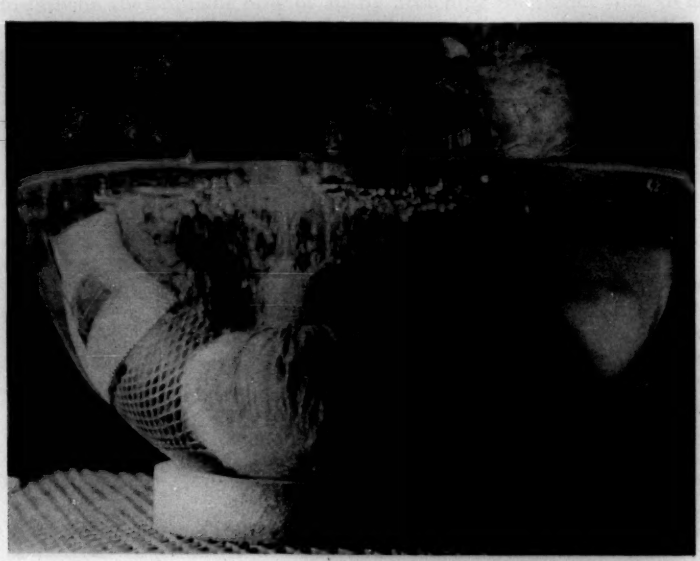

FIG. 1. The Bubbler in Operation in Freshly Inoculated BRF Medium.

the tube to hold the cloth so tightly to the glass that air will escape through the cloth rather than through the neck of the bag.

The bubbling tube is mounted in a rubber stopper to fit the culture vessel. Outside the flask it is connected by rubber tubing to a calcium chloride tube filled with cotton, which acts as a sterilizing filter for the incoming gases. The bubbler with filter in place is wrapped in paper and autoclaved.

It is also necessary to provide an outlet tube for the aerating gases. As shown in Fig. 2 this consists of a bent piece of glass tubing passed through the stopper. It may be loosely plugged with cotton, though the outflowing gases effectively prevent contamination from this source.

If the culture foams excessively it is well to leave this tube open and to hang over it a flask containing a few drops of capryl alcohol and a disinfecting solution.

Aeration. In the Biochemical Research Foundation laboratory, air is obtained from the compressed air supply, and CO_2 from commercial cylinders of the gas. The desired mixture is obtained by measuring the rate at which the two flow into a common delivery tube. Rate of flow is determined with sufficient accuracy by means of easily constructed

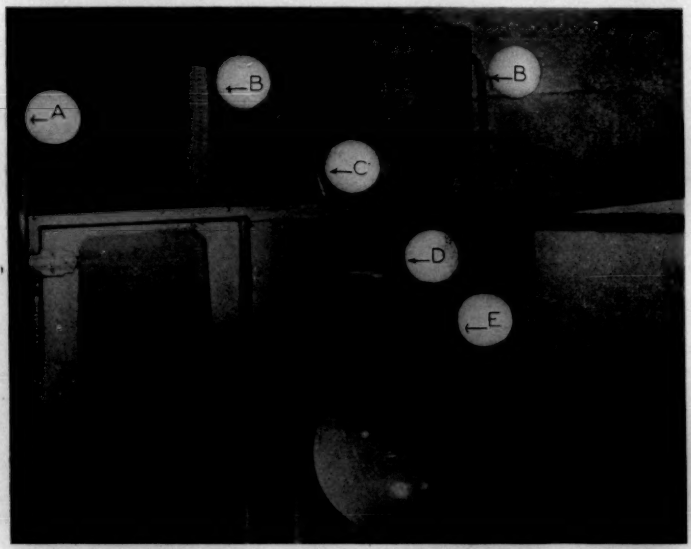

FIG. 2. A BRF Culture of *Vibrio cholerae* Nearing Completion, with Devices Used to Control Aeration in Place. A—Pressure Regulator. B—Venturi Meters. C—Trap. D—Filter. E—Gas Outlet. The extremely heavy growth is indicated by the turbidity.

Venturi-type meters shown in the second illustration. A pressure regulating device, at the left side of Fig. 2, is needed to compensate for fluctuations in air pressure. From the air line extends a long capillary side arm, opening near the bottom of a three-foot column of water which is contained in a six-foot length of glass tubing.

We have also found it desirable to include a trap between the meters and the culture vessel, so that the medium will not be contaminated in the event that sudden changes in pressure force the liquid out of the meter and into the air lines. The trap, shown next to the thermometer

in the illustration, is a suction flask with a T-tube mounted in the mouth and the delivery tube attached to the side arm. The delivery tube is provided with a rubber stopper which fits the filter tube on the bubbler.

The essential feature in aeration is a continuous flow of well dispersed bubbles containing approximately 20 per cent. CO_2. This may, if desired, be supplied in other ways. A cylinder containing a mixture of 20 per cent. O_2, 20 per cent. CO_2 and 60 per cent. N_2 will do very well and in this case the flowmeters are not essential. It is also possible to provide the requisite flow of air by attaching the outlet tube to an aspirator, and the CO_2 could probably be provided by means of a Kipp generator if necessary.

We have generally employed a rate of flow of aerating gases of about 2 liters per minute. With liter cultures in 3-liter flasks this is more than adequate. There is some reason to believe, however, that ideal conditions of aeration have not yet been attained when 13 liters of culture are used in 22-liter flasks. The larger vessel is shown in use in Fig. 2, and the culture illustrated is typical. From a water-clear inoculated medium as illustrated in Fig. 1, the culture has developed a turbidity equivalent to 5000 p.p.m. of silica. In 1-liter cultures twice this population is regularly attained.

Half a gram of phenylmercuric nitrate or acetate will completely sterilize the 13-liter culture in about 5 minutes. In this concentration it is not toxic, and has been regularly employed by us for production of BRF vaccine. Due to the heavier growth in smaller cultures we use $\frac{1}{4}$ gm. of the disinfectant per liter when the 1-liter batches are prepared. Thioglycollate broth must be used in making sterility tests, since the antiseptic employed is a mercurial product. While it is an effective agent in killing the vibrios, it does not provide positive protection against contamination by certain other organisms, and it is essential that every precaution be taken to insure absolute sterility.

PROPERTIES OF THE VACCINE.

The final product is a killed culture of *Vibrio cholerae* with a turbidity of 5 to 10 thousand parts per million of silica. The glucose has completely disappeared, and the terminal pH, before loss of CO_2, is in the neighborhood of 6.8. The filtrate passing through a Seitz sterilizing pad contains only about 0.05 mgs. of nitrogen per cc., some of which must be ascribed to bacterial products. The concentration of non-specific antigenic material must therefore be very small.

Concentration of the culture *in vacuo*, followed by dialysis and finally pervaporation through the dialysis bag provides a rich source of chemically pure vibrios and their large molecular by-products for chemical and physical analysis.

The vaccine has been subcutaneously injected in 0.1 and 0.2 cc. doses in human volunteers without objectionable reactions. A very

slight erythema was the rule, with a few cases of slight swelling and soreness. None of the reactions was sufficiently disturbing to cause any concern or loss of time from work. Serum obtained from these vaccinated individuals was found to equal in mouse protection tests that obtained from persons vaccinated with the present commercial product.

While the tests made to date are not of sufficient weight to merit claims of immunogenic superiority, certain advantages can be reported. The BRF vaccine is administered in a *single small dose*, which is a definite advantage when dealing with populations such as require protection against cholera epidemics, both because of the difficulty in getting individuals to return at intervals for a series of injections, and because of *the smaller amount of vaccine* which must be transported and stored. The immunity provided by *the single injection of BRF vaccine* has persisted apparently undiminished for 9 months at the time of writing, and may be expected to remain at least a year, if not longer.

BOOK REVIEWS.

MR. TOMPKINS EXPLORES THE ATOM. 97 pages, illustrations, 17 × 22 cms. New York, The Macmillan Co., 1944. Price $2.00.

Those who have read "Mr. Tompkins in Wonderland" will appreciate how fantastic and interesting a book of this nature can be and how at least a bowing acquaintance can be obtained at the same time with the theories of modern physics. The book at hand, like its predecessor, is a stretch of the imagination to the realm where the reader is brought into close contact with the infinite as well as the infinitesimal. And our hero, Mr. Tompkins, the modest bank clerk who is happily married, is the means of doing this. His father-in-law is professor of physics at the nearby university and it is through the professor's stories of the physical world that Mr. Tompkins and his wife, Maud, are brought to visualize the wonders of nature. In one chapter Maud is taken on a tour among the molecules inside of her husband's whiskey and soda. In another chapter Mr. Tompkins goes dancing with the electrons of an atom of chlorine and is annihilated in the encounter with a murderous positron. In still another chapter Mr. Tompkins learns the mysteries of the atomic nucleus watching the tricks performed for him by an unusual person who seems to be a cross between the character of Gepetto from "Pinocchio" and Lord Rutherford. The book makes fascinating reading for everyone.

R. H. OPPERMANN.

THE CHEMISTRY OF CELLULOSE, by Emil Heuser. 660 pages, illustrations and tables, 14 × 22 cms. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1944. Price $7.50.

After more than one hundred years of research on the behavior of cellulose with most varied treatments there is now a generally accepted chemical constitution of cellulose chain molecules. As scientific knowledge advanced, the commercial uses of cellulose and cellulose derivatives became more numerous until today its use is widespread; and while scientific knowledge is profuse, it is distinctly recognized that much remains to be acquired. The book at hand reviews the literature on the chemistry of cellulose in the fashion of an unbroken treatise.

At the outset consideration is given to the microscopic and submicroscopic morphological structure of cellulose, and its colloidal nature as it manifests itself in its solid form as well as in dispersions and solutions. Very interesting photographs of the fiber, some under the electron microscope and some in polarized light, illustrate the text. Under the topic of reactions with water it is pointed out that it is still a matter of discussion whether the attraction for water and aqueous solutions leads to chemical combination between the water molecules and the hydroxyls of the cellulose and to chemical combinations in stichiometric proportions. The swelling of fiber is discussed with the reaction of cellulose with aqueous alkalies. Then there follow reactions of cellulose with organic bases, ammonia and concentrated salt solutions; the action of cuprammonium hydroxide on cellulose, cellulose esters, cellulose xanthates, cellulose ethers, and the complex phenomenon of the oxidation of cellulose. Considerable space is devoted to the decomposition of cellulose by acids, when exposed to heat for a period of time, and by biological processes.

The coverage as a whole shows experimental evidence from which can be visualized the individual cellulose molecule as a chain composed of glucose residues united by 1,4-glycosidic linkages of the β-type. Near the end of the book is a brief review and summary of the various facts which have contributed to the establishment of this structure. It is stated that the question of how many glucose residues compose the chain molecules of cellulose as it exists in the plant is still unanswered, and even the shortened chain length of preparations as they result from the isolation by common methods is by no means a definite figure. A knowledge of the

chain length is of importance for it influences the behavior and usefulness of cellulose. The last chapter of the book is devoted to the molecular weight of cellulose and it is pointed out that, provided that the chain molecules of a polymer are not branched by side chains, the average chain length of the aggregate equals the molecular weight. At the end are author and subject indexes.

This book is a digest of world wide literature, well classified and expertly tied together to form a presentation in logical sequence. It gives an accurate picture of the present position of the chemistry of cellulose.

R. H. OPPERMANN.

TESTING OF ENGINEERING MATERIALS, by Carl W. Muhlenbruch. 200 pages, drawings, illustrations and photographs, 16 × 24 cms. New York, D. Van Nostrand Company, Inc., 1944. Price $2.75.

This is a laboratory manual designed for a one-semester course covering the testing of specialized materials for civil, mechanical, or electrical engineering courses. After a review of those properties of materials which can most readily be illustrated in the testing laboratory there are general information on the method of conducting laboratory experiments and instructions for writing reports. There are eighteen experiments including the use and calibration of testing machines, the effect of carbon content upon the properties of steel, flexural test of a wood beam, tension test of non-ferrous metals, the physical properties of concrete, strain gages and their use, and test of a helical spring. At the beginning of each experiment laid out in the book, there is an introductory section giving briefly an outline of the subject, the reasons for making the test, and how far the results are applicable in practice. Next the experimental procedure is given, listing the apparatus needed as well as the material. In cases where there is a choice of different kinds of apparatus which will do the same work, as in the experiment on hardness testing involving the Brinell, Rockwell and Shore testers, the experimental procedure for each is given. The preparation of the report and computations are explained in detail. Somewhat unusual is the discussion following in sufficient detail to enable the answering of questions which may be included.

Many engineers are too prone to adopt the attitude of the non-engineering or non-technical man and consider the term "strength" as some abstract property by which a material may or may not be able to qualify for some particular use. Evidences of this are widespread, not only in cases where there are applications of new materials and structures but particularly where long time existing materials and structures are over-loaded or over-burdened. When viewing some of this evidence, the value of a book, which so comprehensively puts forth these experiments, is brought home. The book is a text devoted to tests. The knowledge gained through the procedure and results of the tests will have use many times in the career of civil, mechanical and electrical engineers.

R. H. OPPERMANN.

ELECTRON-OPTICS, by Dr. Paul Hatschek. 161 pages, drawings and photographs, 16 × 24 cms. Boston, Mass., American Photographic Publishing Co., 1944. Price $3.00.

The use of electron beams which are so guided, collected, dispersed or refracted as to perform tasks similar to those done by light beams is known as electron-optics. It is a young and worthy field of research and its practical applications are many. The advent of war has spurred activities in electron-optics to unbelievable proportions whose results cannot be fully known until the return of peace makes it possible to disclose all of them.

This book has for its purpose to show the foundations of electron-optics and to sketch a few outlines of theoretical principles and so to arouse interest in the basic problems of this field of endeavor. Only plain language is used throughout and the explanation is made without the assistance of mathematics. It begins with the flow of electricity in a vacuum and traces developments chronologically in related fields, finally adding them up in the topic of lenses. Lenses produced by electric and magnetic fields and the motion of electrons in the magnetic field are observed. The proof of Störmer's theory on the northern lights is exhibited in an

interesting manner. Going further into optics, the book explains the electron microscope, the television and the recording tube, amplifying tubes, electron multipliers, light controlled and voltage controlled multipliers. At the end is a bibliography and subject index.

Those who wish to know something about electron optics and those who may desire to make a career in this field will find this book valuable and easy to read.

R. H. OPPERMANN.

HACKH'S CHEMICAL DICTIONARY, Completely revised and edited by Julius Grant. 925 pages. Philadelphia, The Blakiston Company, 1944. Price $12.00.

Chemistry has progressed to a point where it is so large that many who are engaged in chemical industries are often at a loss when encountered with new names and terminology. New processes have been developed which may be entirely foreign to work at hand or may even be a border line subject, and new words are coined. This sort of thing has been more pronounced in the past ten years than previously. A chemical definition of these new words in the form of a description or formula will suffice to make acquaintance for practical purposes.

This chemical dictionary is a handy book for such situations. It is in its third edition, insuring up-to-dateness. The most valuable feature of a work of this type is the style, extent, and conciseness of the definitions. The chemist or engineer should have no difficulty in obtaining a quick understanding from the definitions and there are over 57,000 of them in this edition. The book has 925 pages, large enough to be dependable, yet not so large as to be bulky. The words are arranged in dictionary fashion for quick and ready reference.

R. H. OPPERMANN.

DYNAMICAL ANALOGIES, by Harry F. Olson. 196 pages, illustrations, 14 × 22 cms. New York, D. Van Nostrand Company, Inc., 1943.

Early in engineering education analogies are used when it is desired to facilitate visualization. Perhaps the oldest is the similarity between the water circuit and the electric circuit. The equations of motion of mechanical systems were developed a long time before any attention was given to equations for electrical circuits. For this reason, it was natural to explain the action in terms of mechanical phenomena. The importance of the use of analogies is recognized and consequently a demand has grown for a work on the subject. The author of this book takes the stand that electrical circuit theory now is developed to a much higher state than the corresponding mechanical theory and that more engineers are familiar with it, so that it is logical to apply electrical theory knowledge to the solution of vibration problems in other fields, such as mechanical and acoustical systems. Differential equations are used to show the bases for the analogies.

After giving a series of definitions, a description is given of the electrical, mechanical, rectilineal, mechanical rotational, and acoustical elements. This leads on to systems of one, two, and three degrees of freedom. Corrective networks, wave filters, transients, driving systems for converting electrical to mechanical and acoustical vibrations, generating systems for the reverse conversion are subjects which follow, all of which describe dynamical laws in common. There are other laws, well known in electrical circuit theory, covered by illustrating the application of reciprocity, Thevenin's and superposition theorems. At the end of the book a few typical examples are given of the use of analogies. These include the automobile muffler, the electric clipper, direct radiator loud-speaker, vibrator insulation, etc. There is a subject index.

The principles laid out should assist in making analytical studies and in the application of mathematics to the various systems.

R. H. OPPERMANN.

THE CHEMISTRY OF SYNTHETIC SUBSTANCES, by Dr. Emil Dreher. 103 pages, tables, 14 × 22 cms. New York, Philosophical Library, 1943. Price $3.00.

This work is one of a collection of essays previously published. It was originally written in German but has been translated and here appears in book form in English for the purpose

of giving a survey of the principal questions of macromolecular chemistry as an aid to practice. The chemistry of high molecular organic compounds has experienced an enormous technical rise in recent years so that the importance of the subject needs no more than a brief mention.

The work starts by a consideration of the principles of determination of molecular mass or degree of polymerization. After this there is shown the development of synthetic paint materials, the views concerning the relations between the formation and structure of high molecular synthetic compounds and the film-formation of drying oils, especially synthetic drying oils. Then there is a treatment on the processes of polymerization, the relation between the constitution and the capacity for polymerization, and the influence of the constituents on the capacity for polymerization of non-saturated organic compounds. The principles and processes of polycondensation are given, including a survey of such products which as pure synthesis lead to production and use technologically. The last part of the book is devoted to the solubility of high molecular film-forming substances which covers questions connected with the production of lacs or paint media.

This is a contribution which should find a ready place for those interested.

R. H. OPPERMANN.

PUBLICATIONS RECEIVED.

Chemical Engineering Nomographs, by Dale S. Davis, 311 pages, tables and illustrations, 15 × 23 cms. New York, McGraw-Hill, 1944. Price $3.50.

Basic Mathematics for Engineers, by Paul G. Andres, Hugh J. Miser and Haim Reingold. 726 pages, illustrations, 15 × 22 cms. New York, John Wiley and Sons, Inc., London, Chapman and Hall, Ltd., 1944. Price $4.00.

Hackh's Chemical Dictionary, (Third Edition) Completely Revised and Edited by Julius Grant. 925 pages. Philadelphia, The Blakiston Company, 1944. Price $12.00.

Experimental Spectroscopy, by Ralph A. Sawyer. 323 pages, photographs and illustrations, 16 × 24 cms. New York, Prentice-Hall, Inc., 1944. Price $3.75.

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CURRENT TOPICS.

ARMY AND NAVY NOTES.

Glass Fiber Insulation of New Type Developed for U. S. War Planes.—(*American Glass Review*, Vol. 63, No. 37.) A means of insulating against extreme cold of the stratosphere and also for deadening fatigue-causing sound, is being provided in cabins and flight decks of certain types of United States war planes in the form of glass fibers with a diameter measured in ten thousandths of an inch. The material weighs only four one-hundredths of a pound a square foot when bound with a thermosetting resin and formed into half inch thick sheets. The insulation, known as Fiberglas Type XM–PF is produced by the Owens-Corning Fiberglas Corporation of Toledo.

Particularly on long flights, it has been found that a high sound level within the plane is one of the major factors contributing to the fatigue of the crew. With planes operating at altitudes where temperatures of 60 degrees below zero are commonly encountered, insulation is necessary to reduce the burden on heating equipment, and permit lighter equipment to be used.

The fibrous glass sheets are incombustible and are the lightest inorganic material commercially available for the sound-proofing and insulation of planes. Another important factor is that the sheets gain less than one per cent of their own weight from moisture in the air, when subjected to temperatures of 125 degrees Fahrenheit, and to 90 per cent. relative humidity.

They, therefore, do not cause the dead load of the plane to increase when it is flying through clouds or other humid atmospheres. Organic material frequently used for heat and sound insulation in planes may gain as much as 40 per cent. of its own weight from moisture pick-up under service conditions.

R. H. O.

Shrink-Resistant Process for Army Socks.—(*Textile World*, Vol. 94, No. 5.) The natural tendency of wool to felt has, to this date, been a stumbling block in obtaining satisfactory service and wear from part-wool socks and from underwear used by the Army. Recent developments made by the Research and Development Division of the Philadelphia Quartermaster Depot have advanced to such a stage that some hosiery mills are now treating for shrink-resistance, part-wool Army socks.

One advantage obtained by these mills using these processes, in addition to shrink-resistance, is a greater penetration of the dyes applied to the wool fibers, resulting in a slight saving of dyestuffs. However this treatment doubles the time required in wet finishing and unless a mill has available capacity or additional equipment additional working time is required. Also because of the deleterious effect of incorrect application on both the wool fibers and the dye penetration, a close chemical control is essential. Chemical treatment of socks to prevent shrinkage has proved practicable, and in time it is hoped that arrangements can be made to have all Army part-wool socks so treated.

Exhaustive tests indicate that treated socks will wear up to 40 per cent.

longer than those untreated. Laundering tests have been developed at the Q. M. Depot which will subject the socks to an amount of felting action equivalent to several launderings in the field. Results of tests on untreated socks showed that they were so badly felted that it was impossible to run one's hand inside of them. The chemically treated sock did not felt or shrink and practically all of the original elasticity in the sock was present. While recent changes in sock specifications, namely from the use of not lower than 60S wool to an average of 56S wool in the leg, and 54S wool in the foot, have contributed towards reducing sock shrinkage, the chemical treatment is responsible mainly for shrink-resistance and felt-resistance.

The chemical shrink-resistant treatment depends on the chlorination of wool fibers in the socks, and actually causes some degradation of the wool. Hypochlorites are used in conjunction with other retarding agents which produce a buffer effect. By this method, together with strict control of concentration and processing time, extensive damage to the fiber is prevented.

The technical problems involving the choice of chemicals and the actual processing to prevent over-treating of the socks are being given careful consideration by the Philadelphia Q. M. Depot. Also, the development of suitable test methods and standards which may be employed by the laboratory inspectors is also being worked out. When these problems have been solved, definite specifications covering shrink-resistant treatment of socks will be issued.

R. H. O.

In Back of a Week.—(Industrial Bulletin of Arthur D. Little, Inc., No. 200.) The first week of last May was 100 Octane Week, so designated by the Army, the Navy and the Petroleum Administration for War, because ten years ago the Army Air Corps received from the Shell Oil Company Inc., its first 1000 gallons of iso-octane, which today comprises a large part of our aviation gasoline production. Iso-octane, which does not occur in useful quantities in nature, was first prepared in the work of the Ethyl Corporation by Dr. Graham Edgar and his associates, who proposed it in 1926 as the standard of perfection against which anti-knock "octane rating" of automobile and aviation gasoline could be measured.

By this system the octane rating of gasoline is determined by comparing its tendency to knock with that of a blend of iso-octane (known in strict chemical terminology as 2,2,4-trimethyl pentane), rated as 100 on the octane scale, and n-heptane, rated as zero. The octane number is the percentage of iso-octane in a blend which just matches in knocking tendency the gasoline being tested. The n-heptane standard fuel was obtained by distillation from the oleo-resin exuded by the Jeffry pine tree, growing in the California Mountains.

The wide acceptance of this rating system created an immediate demand for the almost non-existent iso-octane. Arthur D. Little, Inc. at that time was engaged in pilot plant research on production of a number of alcohols from petroleum, a phase of chemistry which has grown to a large industry. This experience attracted the attention of the Ethyl Corporation and as a result the first hundred gallons of iso-octane were made in the Cambridge laboratories of Arthur D. Little Inc., the first gallon being shipped on August 11, 1927 and billed at $25 per gallon.

It was not until 1934, however, that iso-octane was produced in quantities

permitting its use in aircraft fuels. Previous to that time the research laboratories of the Shell Development Company, under the direction of Dr. E. C. Williams, had worked out a pilot plant process for its production. Its existence was made known by Dr. Williams to the U. S. Army, who ordered 1000 gallons.

The price quoted was $2.40 per gallon. The history of iso-octane and similar fuels as components of aviation gasoline was begun. Today commercial iso-octane is made at reasonable cost in tremendous quantities under trade names such as "alkylate" and "hydrocodimer" by a variety of processes developed to fit circumstances at individual refineries.

R. H. O.

Color Scheme Important as Aid to Production.—(*Steel*, Vol. 114, No. 24.) The proper relation of color tones in the factory can have much to do with the productive effort of the plant as a whole and with productivity of individual workers, according to color authorities. Pleasing tones in decoration of walls and ceilings and strictly utilitarian application of color for safety precautions around machines and marking of their controls for ease of operation are believed to have good psychological effect on the war effort generally and tangible results in higher output.

Use of proper tones in painting an automatic riveting machine, for example, can mean less fatigue on the part of the operator and, therefore, less chance of accident. The understanding of the relationship of light to color can mean a steadier and better operation of nearly all kinds of machines, with less chance for spoiled materials. While pleasing color tones in rest rooms and lunch rooms can mean improved employer-employee relations—tending toward reduction of absenteeism and labor-turnover—the most vital use of color is that in conjunction with machinery.

Faber Birren, color consultant who recently completed a color coordination scheme for Henry Disston & Sons, Inc., Philadelphia, saw manufacturer, including everything from assembly and personnel departments to an employee sun lamp room, maintains that too much color may be visually and psychologically distracting to people working with materials which are neutral in shade or colorless, since it would handicap their attention to the job and thereby lower efficiency. He says physical and emotional relief is obtained through a "change of pace" in color throughout the plant. Each specification must be tailor-made to accord with lighting, operation of machine, distance from walls and many other factors which only an expert can properly evaluate.

R. H. O.

Electric Motor Operates at 120,000 R.P.M.—An electric motor operating at the record-breaking speed of 120,000 revolutions per minute, or more than seven million revolutions per hour, has been built and tested by General Electric. The motor was developed for application to internal grinding machines used in finish-grinding small holes, many less than 1/4 inch in diameter, in vital war parts. Another possibility for its use is in driving small drill chucks for drilling tiny holes in soft metals, using drills 1/32 inch in diameter and less.

According to F. W. Baumann and D. H. Ware, General Electric motor engineers, the surface speed required to produce a high grade finish economically

by grinding should be about the same whether grinding a small or large hole. A medium size wheel rotating at a moderate speed gives the requisite surface speed but for small holes only a tiny grinding wheel can be used; hence the high rotating speed is essential.

With normal voltage applied at 2000 cycles, the new motor reaches full speed in less than a second. It is rated 3 horsepower and weighs but seven pounds, as contrasted with the standard 3-hp, 1800 r.p.m. motor which weighs 105 pounds. The motor is so small that it fits into the palm of a person's hand, while its rotor is scarcely larger than a man's thumb.

Tests the motor has passed successfully at 120,000 r.p.m. include eight-hour continuous runs at rated horsepower, as well as grinding tests with a tiny grinding wheel mounted directly on the motor shaft.

Problems entering into the design of the motor were largely of a mechanical nature. Since the utmost in smooth operation is an essential to precision grinding, ultra-precision bearings with practically perfect dynamic balance were required. A special oil mist lubricated type of bearing is used. The amount of material used in the motor is so small, with a constant reduction in radiating surface, that water cooling is utilized, one-half gallon a minute being used.

R. H. O.

"Bug Bombs" Protect Soldiers' Health.—(*Compressed Air Magazine*, Vol. 49, No. 6.) Small metal containers charged with a powerful insecticide and high pressure Freon gas are used by our armed forces in tropical areas to kill mosquitoes, flies, and similar disease spreading pests. When a soldier wants to rid his tent of vermin, he unscrews a cap from a needle sized tube extending down into the container or "bug bomb." Propelled by the gas, the insecticide issues in the form of a spray, and enough of it is discharged in three seconds to kill all the insects in a pup tent. Each dispenser contains one pound of insecticide, sufficient for 12 to 14 minutes of spraying, or for the eradication of the insect life in 240 pup tents or 50 large bombing planes.

The insecticide, which is called aerosol, is a mixture of pyrethrum and sesame oil. It was formulated by the U. S. Department of Agriculture and is harmless to humans. The container was developed by engineers of the Westinghouse Electric and Manufacturing Company and is thrown away when empty. Its designers were faced with the problem of providing something inexpensive and light but at the same time strong enough to withstand up to 2000 pounds pressure per square inch. They succeeded by making it of metal 44/1000 inch thick and by brazing to it a clover leaf shaped rupture disc that serves as a safety valve. If a dispenser is subjected to great heat —as may happen in a ship's hold—the internal pressure will build up to as much as 700 pounds. Under such a condition the rupture disc will function and permit the gas to escape slowly, thus averting the danger of an explosion.

Up to March 1, more than 7,000,000 bug bombs have been shipped to the fighting areas. Collectively they would kill the insects in 70,000,000 homes, which is nearly twice the number in the United States. The expectations are that they will become generally available after the war for insect control in homes and farm buildings. It is also possible that they may be converted

into spray guns by substituting thin paints or lacquers for the insecticide and used for coating furniture, automobiles, etc.

R. H. O.

Power Trains.—C. M. Laffoon of the Westinghouse Electric and Manufacturing Company in an address to the American Society of Mechanical Engineers, Pittsburgh, described the 5000 kw. and the 1000 kw. mobile power plants built to supply the needs of the United Nations.

In countries where the electric power plants have been destroyed or put out of commission a certain amount of power is required by the occupying Army or Navy over and above their normal power supply needed for primary military operations, to operate base hospitals, machine shops, repair shops, and replacement parts manufacturing plants. Likewise, a similar minimum amount of electric power is required by the civilian population to operate hospitals, re-establish and operate water supply and sewage systems, operate repair shops and manufacturing plants for machine tools, and carry on other projects which are vital to the beginning of a rehabilitation program, to enable the civilian population to become self sustaining and to effectively coordinate and cooperate with the military program.

It is felt by some authorities that the total amount of mobile power plant capacity required for a particular area should be on the order of 2 to 3 per cent. of the generating capacity existing in the area previous to the devastation.

The Westinghouse Electric and Manufacturing Company is now building for our Allies 24—1000 kw. and 10—5000 kw. portable, self contained steam electric power plants. These power plants are assembled in specially designed railway cars which, with suitable trucks, can be transported over most American and some foreign railroads, and can be operated to generate electric power when located on satisfactory railway sidings and provided with necessary supplementary foundation supports.

The specification requirement that the power plant operate with a minimum loss of water made it necessary to use a closed steam cycle and air cooled condensers. Space and weight limitations, and reliability were important factors in determining the steam conditions for the 5000 kw., 3000 r.p.m. prime mover to be 600 lb./sq. in. gauge and 750 deg. Fahr. at the throttle, and exhausting at 2 lb./sq. in gauge. Under these steam conditions the turbine generator will require 80,000 lbs. of steam per hour to produce a gross generator output of 5000 kw. Eight railway cars of the freight type and approximately 50 ft. long are required to house and support the main and auxiliary power plant equipment.

The 1000 kw. Power Train unit consists of one boiler car, one turbine generator car, one cooling tower car, and coal handling equipment.

R. H. O.

Forecasts Higher Temperature and Pressure for Merchant Ships.—Higher temperatures and pressures for propulsion turbines will offer a logical means of obtaining more economical merchant ship operation, especially if the cost of fuel goes up after the war, according to A. Kennedy, Jr., assistant to the manager of General Electric's Federal and Marine Divisions.

In an address recently before the Metropolitan Section of the Society of

Naval Architects and Marine Engineers in New York, Mr. Kennedy pointed out that "every increase of approximately 25 degrees in steam temperature for a given pressure means an improvement of approximately one per cent. in heat rate."

Stating that the Navy has for several years operated a destroyer using 1200 lb., 900 F. steam, Mr. Kennedy indicated that merchant ship turbines can and will be built for those conditions. A great share of the credit for progress up to the present, according to the speaker, is due to a few progressive ship builders, naval architects and operators.

The problem of designing marine turbines for higher pressures and temperatures has been materially simplfied for manufacturers who have had years of experience in building similar machines for large central station power plants, Mr. Kennedy said

Along with higher steam conditions, higher turbine rotative speeds also offer many advantages according to Mr. Kennedy.

"Some of these advantages are improved efficiency and shorter spans between bearings, thereby simplifying expansion problems due to temperature. Shorter spans mean fewer alignment problems, smaller shafts and less packing leakage; higher revolutions mean lower weights and tend to lower costs," he said.

R. H. O.

Quick Acting Brake.—A new magnetic brake, which will stop a one-eighth horsepower motor traveling at 16,000 revolutions per minute in less than six turns, has been developed by Chester I. Hall, General Electric engineer. It promises to have wide use in the operation of equipment for the armed services.

"Another way of expressing the force with which this new brake works can be gained by comparison with an automobile," Mr. Hall explained. "The outside edge of this rotor, moving at 16,000 r.p.m., is traveling at 62 miles per hour. In stopping it within six turns would be the same as bringing this mile-a-minute auto to a dead stop in 2.73 feet.

"It is called a magnetic brake but magnetism plays no part in its stopping operation. A cork shoe and friction does the trick," according to Mr. Hall. "Magnetism releases it once the need for braking is removed. The motor is braked at all times, except when current is applied."

Another feature of this brake, from a manufacturing viewpoint, is that there are but 15 parts, compared to 51 parts in the model previously used for this purpose.

R. H. O.